

GLASSHOUSE CROPS  
RESEARCH INSTITUTE

ANNUAL REPORT

1958

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LITTLEHAMPTON · SUSSEX

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1958

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## THE GLASSHOUSE CROPS RESEARCH INSTITUTE

The Glasshouse Crops Research Institute was established on the 8th September, 1953, as a company limited by guarantee, but without share capital, under the Companies Act of 1948. Its registered office is at Littlehampton, Sussex, where the main research station is being developed. The Institute grew out of the Experimental and Research Station at Cheshunt, which was in existence from 1915 to 1954, and has also absorbed the work of the Mushroom Research Station at Yaxley which functioned from 1946 to 1954.

In the Memorandum of Association the principal object for which the Institute has been established is laid down as follows:

“To promote scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto.”

The Institute is administered by a Governing Body consisting, at present, of fourteen members including the Chairman, Mr. T. Ainslie Robertson. Of these, six are well-known commercial growers who represent the branch of horticultural industry served by the Institute, six are eminent scientists, and one is a Senior Education and Advisory Officer of the Ministry of Agriculture. The Governing Body is appointed by the Lord President of the Council and the Minister of Agriculture, Fisheries and Food.

The Institute is financed almost entirely by grants from the United Kingdom Treasury. From 1st April, 1956, these have been administered by the Agricultural Research Council which exercises general supervision over the Institute's staffing and research programme.

The Institute has a Subscription Scheme whereby growers and others may associate themselves with its work. For a small annual payment subscribers obtain certain privileges which enable them to take a closer and more personal interest in the research that is being carried out at the Institute. The principle minimum subscription rates are five guineas per annum for firms or companies, and two guineas per annum for growers working on their own account or for other individuals interested. The main privileges for those subscribing are receipt of the Annual Report and attendance at the annual Open Day. Further particulars of the scheme may be obtained from the Secretary of the Institute.

The Institute's research station at Littlehampton is situated in the heart of the important West Sussex glasshouse area. This is also an important area for mushroom production. The station is thus well placed for its work and for maintaining contact with important sections of that branch of horticultural industry which the Institute has been set up to serve. The research station covers 98 acres, and includes 41 acres arable and about  $18\frac{1}{4}$  acres of rough grazing, the remainder being kept as amenity grassland. The greater part of this land is required as a reserve for future work with outdoor crops, for the supply of loam, and for re-soiling the glasshouses when experimental work requires it.

The Institute's physical development has reached an intermediate stage. There is a well-equipped block of laboratories with an annexe for special services. There are also at present 1.55 acres of permanent glass for experiments and trials, as well as research glasshouses for work in the fields of plant physiology, plant pathology, chemistry and crop protection. A special unit, including three growing houses, for work on mushrooms completes the research facilities, which are supported by a wide range of ancillary buildings, such as boiler houses, potting sheds, stores, etc.

The scientific and experimental staff of the Institute at present numbers 28, most of whom are honours graduates.





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# GLASSHOUSE CROPS RESEARCH INSTITUTE

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# GLASSHOUSE CROPS RESEARCH INSTITUTE

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## Director

F. W. TOOVEY, O.B.E., B.Sc. (Lond.), A.R.C.S., A.I.C.T.A., M.I.BIOL.

## SCIENTIFIC STAFF

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### Assistants (Scientific)

Mrs. B. COOPER, R. BROWN, Z. J. KULWIEC, Miss P. CLARK (*from 1.11.58*),  
Miss C. JONES (*from 1.12.58*), W. T. SPARROW (*27.5.58 to 10.9.58*)

### Chemistry

G. W. WINSOR, B.Sc. (Bristol), Ph.D. (Lond.), D.I.C., A.R.I.C.

J. N. DAVIES, B.Sc., Ph.D. (Lond.)

J. H. L. MESSING, B.Sc. (Wales) (*seconded to British Guiana*)

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D. M. MASSEY, B.Sc. (Bristol)

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A. M. GREENWAY, Miss M. COLEMAN

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R. J. SMITH, B.Sc. (Lond.)

J. T. HUGHES, B.Sc. (Lond.), A.R.I.C.

Miss V. A. GENTLE, B.Sc. (Hull)

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Miss J. MARTIN, Miss B. HOTSON, Miss B. FINCH

### Plant Breeding

L. A. DARBY, B.Sc. (Wales)

### Assistant (Scientific)

J. W. M. SMITH

### Statistics

D. COOKE, M.A., DIP.STAT. (Oxon.) (*from 1.10.58*)

### Assistant (Scientific)

Miss E. J. WINGATE (*from 17.11.58*)



## Plant Pathology Division

L. BROADBENT, D.Sc. (Lond.), Ph.D., M.I.BIOL. (*from 1.8.58*)

### **Entomology**

N. W. HUSSEY, B.Sc. (Wales), Ph.D. (Edin.)

W. J. PARR, M.I.BIOL.

I. J. WYATT, B.Sc. (Lond.), Dip.AGRIC.SCI. (Cantab.), Dip.TROP.SCI. (Trinidad)

Miss B. GURNEY

### **Mycology and Virology**

P. H. WILLIAMS, B.Sc. (Lond.), M.I.BIOL.

R. HOWLES, B.A., Ph.D. (Cantab.)

Miss M. H. EBBEN, M.A. (Cantab.), M.I.BIOL.

Miss D. G. GANDY, M.Sc. (Lond.)

Miss O. M. STONE, M.A., Ph.D. (Cantab.)

### *Assistants (Scientific)*

R. PAWLEY, Miss P. SHOESMITH, Miss J. KERNER

---

### **Technical Services Unit**

J. E. MORTON, A.R.P.S., F.R.M.S., M.I.BIOL.

### *Assistant (Scientific)*

Miss G. MARSH

### *Maintenance*

R. MINGAY, B. ROCKALL (*from 24.11.58*)

## **ADMINISTRATION**

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J. BISHOP, A.C.I.S.

### *Assistants*

Mrs. E. J. BESWICK, Miss R. GURTEEN, Mrs. B. MACDONALD (*until 13.9.58*),

Miss M. M. K. BALDWIN, Miss R. M. JONES (*from 1.10.58*)

### **Librarian**

Miss G. DUNSTER, B.A. (Lond.)

## **NURSERY STAFF**

### *Nursery Manager and Demonstrator*

J. M. EVANS, N.D.H.

### *Foreman*

T. W. SYER

### *Assistants (with more than three years' service at 31.12.58)*

F. BLAKE (30 years), R. FROST, L. TOMS, P. DAWES, W. HOTSTON, Miss R. MILLS, Mrs. J. HOTHER,  
S. BARNETT, G. MORRISON, N. J. JACKSON, Miss A. RICH.

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## I. INTRODUCTION

An important change has been adopted in the presentation of this report which it is hoped will find general acceptance. Research departments will now report their work in general terms, and detailed accounts will be published, either in the Institute's report or in scientific journals, only when the work reaches a suitable stage for such reporting. A number of special articles, reviews and reports are included in this report.

### Governing Body

The Fourth Annual General Meeting was held on 12th February, 1958, when the Chairman's Report and the Accounts and Balance Sheet for the year ended 30th September, 1957, were approved and adopted. Two ordinary meetings of the Governing Body, the Eleventh and Twelfth, were also held during the year for general business. The General Purposes Committee did not meet but dealt with certain business by correspondence. The Staff and Research Committee met at the Institute for two days, on 30th and 31st January, to consider the research programme for the following three years. This committee also met on two other occasions to interview candidates for scientific staff appointments, and took the opportunity of dealing with other business at the same time. The special Heating Sub-Committee, under the chairmanship of Lt.-Col. L. R. Leach, met on 14th March and 17th December.

### Staff

Dr. L. Broadbent, B.Sc., Ph.D., D.Sc., of the Rothamsted Experimental Station, was appointed Head of the new Research Division formed by the amalgamation of the Departments of Entomology and Plant Pathology, and assumed duty at the Institute on the 1st August.

Mr. D. Cooke, M.A., Dip.Stat. took up his duties as Statistician on 1st October on his return from the United States, where he had been holding a one-year appointment as visiting research professor at the Institute of Statistics, North Carolina.

Mr. G. F. Sheard, M.Sc., Director of the Fairfield Experimental Horticulture Station, was offered appointment as Head of the new Horticultural Research Department and is to join the Institute's staff on 1st April, 1959.

There were a number of changes in the staff of Assistants (Scientific) and these are indicated in the staff list published at the beginning of this report. Two new posts in this grade were filled, to provide assistance for the Plant Physiology Department and the Statistician respectively. There was one change in the office clerical staff. A Laboratory Attendant was recruited for the Technical Services Unit.

Seven persons, mostly students, were engaged for varying periods during the summer to assist with the recording of the glasshouse experiments.

### Internal organisation

The Departments of Entomology and Plant Pathology have been amalgamated to form a Division of the research staff. It is hoped that this re-organization will lead to a considerable strengthening of the Institute's work in the broad field of pathology and will enable particular attention to be given to virus diseases, with which Dr. Broadbent, who has been appointed as Head of the Division, has had much experience.

A new Department of Horticultural Research has been created to undertake investigations of a horticultural nature which do not properly fall within the provinces of the other research departments. Initially the Head of the Department will exercise general oversight of the nursery, and will also undertake scientific liaison duties.



## **Capital developments**

The special research glasshouse for the Plant Physiology Department was completed, but a number of difficulties were experienced with the equipment and these delayed bringing it into use until late in the year. The automatic ventilation system has been a particular source of difficulty, and the on-off control installed may prove not entirely suitable for research requirements.

A start has been made with planning new research glasshouses for virus and entomological work.

The mushroom research unit was completed by the spring, well within the period estimated, although it took some further time to install the ventilation system. This system is largely experimental, and its design involved much discussion with various experts. Details of the new buildings were given in last year's report.

The administration building had to be held over for a year, as previously intimated, owing to Government restriction on capital expenditure. In an effort to reduce the cost of the project, and in order to accommodate the staff of the statistical section and so release still more accommodation in the present laboratory block for scientists requiring full laboratory services, the opportunity was taken to carry out a substantial revision of the plans.

A small capital grant was made available for a scheme to provide a warning in the event of a failure of the heating equipment serving the trial and special purpose glasshouses. The system was installed and tested, and has functioned on a number of occasions, mostly because of the occurrence of minor defects. Another small grant was made for constructing more concrete beds in the carnation houses.

Approval in principle has been given for a new propagating house and for a stand-by generator, and these projects are in the planning stage.

## **Trial glasshouses: heating system**

The proposals for modifying the heating system in the trial glasshouses to give better temperature control and uniformity and to provide a more flexible system for research purposes, were given further consideration by the Governing Body's Heating Sub-Committee which met formally twice and held informal consultations on other occasions. The proposals have involved much careful study and discussion with experts. With the agreement of the Director of the National Institute of Agricultural Engineering, Mr. W. H. Cashmore, Mr. L. G. Morris and his colleagues at that Institute very kindly undertook to prepare an outline plan of the new scheme, and their detailed recommendations were received towards the end of the year. Much still remains to be done before they can be carried into effect, and the present intention is to have the new system installed in the late summer or early autumn of 1960 so as to cause the least disruption to the experimental programme.

In the meantime certain interim improvements, also based on N.I.A.E. advice, have been carried out to the present system, a small capital grant being made available for the purpose. The improvements involved the substitution of valves of the on-off type, the coupling up of the two circulating pumps in the boiler house, and the insertion of orifice plates near the motorised valves to match the pressure required to circulate the water in each house to that available. The work was done by the nursery staff. The changes already seem to be giving very much better temperature control at a given point.

## Reserve land

The farming policy for the reserve land has been reconsidered and, after receiving advice from the Land Agency Service provided for A.R.C. establishments by Messrs. W. H. Cooke and Arkwright, it has been decided to put the land down to permanent grazing, the grazing to be let to a suitable tenant in due course. The intention is to sow a ley under a cereal crop in 1959, and to fence the land and lay on water in the autumn or winter so that grazing can commence in the spring of 1960.

The clover-grass ley sown in 1957 was cut in the early summer of 1958 and the stubble ploughed in. Owing to the rather weedy condition of the land it was decided that the maximum amount of winter cultivation would be necessary to prepare it for sowing spring wheat in 1959, and a further ploughing, across the furrows, was undertaken in the autumn. A third and final ploughing will be carried out as soon as conditions permit in the new year.

As mentioned last year, the area which may be required for the erection of glasshouses in the future has been laid down to grass which will be kept mown. This has reduced the area of cultivable land to 41 acres.

## Subscription scheme

There was a small increase in support for the Subscription Scheme. By the end of the year the numbers participating in the scheme were as follows:

|                    |       |
|--------------------|-------|
| Companies or firms | 69    |
| Individuals        | 101   |
| Overseas           | 8     |
|                    | <hr/> |
|                    | 178   |
|                    | <hr/> |

## Miscellaneous

### *Staff social activities*

Among other activities the Staff Association arranged a very successful Christmas party attended by all grades of staff. The Horticultural Society held two shows during the summer as well as the annual allotment competition.

### *Students*

A Ministry of Agriculture post-graduate scholar, Mr. P. J. Sutton, was posted to the Institute for one year from 1st October. He has been attached to the Chemistry Department and is undertaking a research study of some recent developments in the formulation of potting composts, but arrangements are being made for him to obtain experience of the work of the other research departments.

Another student, who has been selected for a degree course at Wye College, is doing his year's practical pre-graduate training at the Institute and arrived on the 15th September. He is to work on the nursery for the first six months, and will then be attached to the research departments for short periods.

### *Liaison*

The Director continues to serve on the various committees previously listed, thus maintaining very useful liaison with a number of bodies with interests in fields related to those covered by the Institute. Dr. Leonard, Head of the Plant Physiology Department, is a member of the



A.R.C.'s Working Party on Research on Environment in Glasshouses. Mr. Read, Head of the Crop Protection Department, attended two meetings of the Horticultural Section of the N.A.A.S. Regional (S.E.) Experiments Committee. Dr. Winsor, Head of the Chemistry Department, is a member of the Bulbs Advisory Panel of the N.A.A.S. Experimental Husbandry Farm at Kirton in Lincolnshire and attended two meetings during the year.

The strong liaison between the Institute and the National Agricultural Advisory Service was maintained in numerous ways.

#### *Open Days*

There was an increase in the number of visitors at the Institute's second annual Open Day which was held in excellent weather on 11th June, over 160 growers and others attending. On the following day, at the request of the Mushroom Growers' Association's Research Sub-Committee, a special demonstration was arranged for mushroom growers. This was extremely well attended, and it is estimated that as many as 160 growers were present.

#### *Other contacts with growers*

The Director and other members of the staff paid a number of visits to commercial nurseries and mushroom farms to maintain the Institute's contact with the industry. Particular mention may be made of those arranged by the West Sussex Tomato and Flowers Working Parties.

#### *Mushroom research*

The Mushroom Growers' Association's Research Sub-Committee met at the Institute on 1st May and 15th September. These meetings provide a useful opportunity of reviewing the progress of mushroom research with the members of staff concerned.

Earlier in the year, on 9th January, a meeting of scientists working on mushroom disorders of the "Watery Stipe" type, and others interested, was convened at the Institute to enable them to pool their ideas and try and co-ordinate their efforts in investigating these complex disorders which have been causing so much concern to growers.

#### *Conferences*

The Director, and Mr. H. R. B. Hack of the Plant Physiology Department, attended the 15th International Horticultural Congress held in Nice from 11th to 18th April. Mr. Hack read a paper entitled "Soil moisture tensiometers: some limitations and applications to growth studies". Mr. Read and Miss Gentle, both of the Crop Protection Department, attended the Conference of Workers on Pesticides at Rothamsted from 23rd to 25th April, and Mr. Parr, of the Entomology Department, attended the International Colloquium on Research Methods in Soil Zoology at Rothamsted from 10th to 14th July. Dr. Broadbent was in the United States from 14th to 31st August, principally to attend the Jubilee Meeting of the American Phytopathological Society at Bloomington, Indiana. Dr. A. J. Cooper, of the Plant Physiology Department, attended the British Association meeting in Glasgow and gave a paper entitled "Growth trends of the glasshouse tomato" at the special horticultural session of the Agricultural Section on 1st September.

#### *Talks by staff*

The Director gave an illustrated account of the Institute's work to the Surrey Horticultural Progress Club at Guildford on 31st January. He also gave talks on the Institute's research on tomatoes at the Glasshouse Conference held at the Pershore Institute of Horticulture on 14th October, and on the general work of the Institute to the North-West Sussex Growers' Mutual

Aid Group at Billingshurst on 13th November and at a Horticultural Conference arranged by the N.A.A.S. at Durham on the 18th November.

Mr. Read gave a talk on recent work on the control of cucumber and other mildews under glass to the Conference of Advisory Plant Pathologists held in London on 4th March. Mr. Read also gave a paper entitled "Pest and Disease Control" at the British Carnation Society's Luncheon and Brains Trust on 29th March. Dr. N. W. Hussey was invited to give a talk on mushroom pests at the M.G.A. area meeting at Blackpool on the 17th October.

### *Visits*

The Director visited Cornwall and the Isles of Scilly from 25th to 27th March to study the disease situation in bulb flower crops. Mr. W. H. Read, Head of the Crop Protection Department, made a similar visit from 20th to 22nd May. While in France for the International Horticultural Congress the Director took the opportunity of visiting the French mushroom research centre at Montesson, near Paris. The Nursery Manager, Mr. J. M. Evans, paid a short visit to Guernsey from 25th to 27th March. The Director and Dr. Leonard visited the John Innes Horticultural Institution on 30th July to discuss with Mr. Lawrence the design of propagating houses and the automatic ventilation of glasshouses. With Dr. Broadbent the Director visited the National Vegetable Research Station at Wellesbourne on 1st December and the Plant Breeding Institute at Cambridge on 11th December, principally to discuss the design of the new virus research glasshouse now being planned, with particular reference to insect-proofing and air-conditioning. Various other members of the staff made a number of visits to research centres and experimental stations in the course of their work. While in the United States, Dr. Broadbent visited the school of Agriculture, Pennsylvania State University, the New York State College of Agriculture, Cornell University, and the Plant Industry Station, Beltsville, in connection with his future work at the Institute.

### *Visitors*

The number of visitors received at the Institute is now very considerable, and are too many to list individually. Among organized parties may be mentioned the N.A.A.S. Glasshouse Group, students from Studley and Wye Colleges, the West Sussex Tomato Working Party, the South Holland Growers' Club (from Lincolnshire), a party of about 50 Chinese students, and members of the Rosewarne E.H.S. (Cornwall) Station Advisory Committee and Flowers Advisory Panel.

Dr. P. J. Bels, who is in charge of mushroom research in Holland, brought a party of Dutch mushroom growers on 3rd October. Other overseas visitors were as follows:

|                        |                                                                                            |
|------------------------|--------------------------------------------------------------------------------------------|
| <i>Australia:</i>      | Mr. Lawson.                                                                                |
| <i>British Guiana:</i> | Dr. H. Evans (Messrs. Booker Bros.).                                                       |
| <i>Canada:</i>         | Dr. C. D. McKeen, Senior Plant Pathologist, Science Service Laboratory                     |
| <i>Denmark:</i>        | K. B. Christensen.                                                                         |
| <i>Egypt:</i>          | Dr. S. K. Gayed, Pathologist, University of Cairo.                                         |
| <i>Finland:</i>        | Miss Kirsti Salokangas, Agricultural Research Centre, Department of Horticulture, Piikkiö. |
| <i>France:</i>         | R. H. Goodson.                                                                             |
| <i>Greece:</i>         | R. Kirkis.                                                                                 |

|                                |                                                                                                                                                                                                                                                                                             |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Holland:</i>                | C. A. Muntjewerff.<br>Dr. J. R. Jensma, Research Director, Bruinsma Hybrid Seed Company, Naaldwijk.<br>J. M. Andeweg, Institute of Horticultural Plant Breeding, Wageningen.<br>Dr. H. A. van Hoof, Mycologist, Vegetable Research Station, Alkmaar.                                        |
| <i>Israel:</i>                 | Mr. Weyel, Ministry of Agriculture.                                                                                                                                                                                                                                                         |
| <i>Italy:</i>                  | Dr. Emidio Taliani de Marchios and Dr. Nemesio Ricci.                                                                                                                                                                                                                                       |
| <i>New Zealand:</i>            | J. P. Salinger, Horticulturist, Department of Agriculture.<br>C. Croall, R.D.I., Hamilton.<br>H. A. L. Morris, Birds Eye, Christchurch.                                                                                                                                                     |
| <i>Nigeria:</i>                | J. B. Davis, Sleeping Sickness Service.                                                                                                                                                                                                                                                     |
| <i>Norway:</i>                 | A. Bakke.                                                                                                                                                                                                                                                                                   |
| <i>Poland:</i>                 | Dr. Emil Chroboczek, Professor of Vegetable Crops at the College of Agriculture, Institute of Vegetable Crops, Skierniewice.<br>M. M. Manczak, College of Agriculture, Skierniewice.                                                                                                        |
| <i>Portugal:</i>               | Dr. B. d'Oliveira, Pathologist, National Agricultural Station.                                                                                                                                                                                                                              |
| <i>Portuguese East Africa:</i> | Tomaz de Carvathe, Direccão de Agricultura and Florestas, Lourenço Marques.                                                                                                                                                                                                                 |
| <i>Spain:</i>                  | Leopoldo Massieu, Agricultural Engineer, Ministry of Agriculture.                                                                                                                                                                                                                           |
| <i>Turkey:</i>                 | Bilal Ozsan, Director of Vegetable Experimental Stations in the Ministry of Agriculture.                                                                                                                                                                                                    |
| <i>U.S.A.:</i>                 | H. S. Ward.<br>Dr. C. E. Yarwood, Virologist, Department of Plant Pathology, University of California.<br>Dr. Leon Kneebone, Professor of Botany, School of Agriculture, Pennsylvania State University.<br>C. Clive Lawrence, Assistant to Assistant Agricultural Attache, British Embassy. |
| <i>Yugoslavia:</i>             | Lazar Aladzajkov, Lecturer in the Faculty of Agriculture.                                                                                                                                                                                                                                   |

### Acknowledgements

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A special word of thanks is due to those many officers of the National Agricultural Advisory Service, and particularly to the Directors of the Experimental Horticulture Stations, for their continued collaboration which has facilitated the Institute's work in so many ways. Finally, the very careful study given to the Institute's heating and ventilation problems by Mr. L. G. Morris and his colleagues at the National Institute of Agricultural Engineering, with the full agreement of the Director, Mr. W. H. Cashmore, has been of untold value, and the Institute is greatly indebted to them for their very willing assistance in dealing with the many complex problems involved.



## THE NURSERY AND EXPERIMENT STATION

by

J. M. EVANS

The experiment station at the Institute's headquarters at Littlehampton, which covers 98 acres, comprises a glasshouse nursery and reserve land, the latter being farmed or maintained as amenity grassland. The nursery includes trial glasshouses, special research glasshouses, and a mushroom research unit. Details have been given in previous Annual Reports.

### **The trial glasshouses**

The total area of glass under this heading is 1.55 acres, including propagating houses and corridors. This is mostly used for large scale or "field" trials, as explained in the 1956 Annual Report.

Tomato experiments occupy one acre of the trial glasshouses. Planting began in late January and continued until early April since propagating space is still at a premium. An additional east-west propagating house of modern design has been approved and it is hoped to have this available for the 1959/60 season.

Sterilisation of the tomato borders was carried out by steaming ( $\frac{1}{4}$  acre) or by treatment with formalin ( $\frac{3}{4}$  acre). For the 1958/59 season all but  $\frac{1}{8}$  acre, reserved for chemical sterilisation only, will be steamed.

The soil-panning problem is still troublesome, but is far less so in the houses watered with automatic equipment. In order to deal with the problem the glasshouse borders are being heavily dressed with composted straw from the arable land, and as a result the soil structure is improving. This will need to go on for some years yet, however.

The remainder of the trial glasshouses is shared by cucumbers ( $\frac{1}{4}$  acre) and carnations ( $\frac{1}{4}$  acre). The cucumber block is steamed annually. The carnation house E3 was completely steamed before replanting. House E2 was concreted over and the compost for the beds was steamed. In E1 only part of the house was steamed for the purposes of a pathological experiment.

### *Heating system*

Late in the year interim improvements were made in the 4in. hot water heating system in time for the 1958/59 season. The rate of flow was doubled, and the motorised valves were changed from a butterfly type to a positive on-off type. It is confidently expected that this will give greater uniformity of glasshouse temperature throughout the various blocks. The propagating corridor, required for germinating cabinets and, later, lettuce seed production and chrysanthemums, is now heated from pipes which heat the new frames built between the propagating houses, instead of off one loop from propagating house no. 3. As a result the latter house is now more uniformly heated. We are grateful to Mr. L. G. Morris and his colleagues at the National Institute of Agricultural Engineering for their guidance in these alterations, which were undertaken by the Institute's own workers.

A further improvement was made by covering all the mains pipe-ducts, which are situated within the glasshouses at the south ends, with concrete slabs. This cuts off most of the heat from this source, which has been a cause of temperature gradients in the houses, and makes a useful pathway in many cases.

### *Constructional work*

With advice from the Fernhurst Research Station, concrete beds were designed for the carnation house E2 for the purpose of Chemistry Department's nutrition experiment. The concrete slabs were made and the beds constructed by nursery labour. The beds have side-drainage to prevent the leachings from one plot passing through the adjacent ones. Special arrangements were made for the complicated plumbing required by the experiment so as to avoid having pipes lying untidily across paths. This house, the middle one of a block of three, was separated on both sides from its neighbours by a glass partition. This was done to prevent the possible spread of disease from house E1 which is used for mycological investigations; for the sake of uniformity the house also had to be separated from E3. Gutter vents were designed and installed to help make up for the lack of side ventilation.

Major constructional work was also undertaken, very largely with nursery labour, in B Block, one of the blocks of four aeroplane-type houses. Again this was for a chemistry experiment on nutrition, this time for tomatoes. The block was divided into 112 separate plots, bricked on four sides down to a depth of 3ft. in the border soil, taking care that the soil was replaced as nearly as possible in its original position. For this operation the whole superstructure was supported on lengths of sleepers while the footings and plot walls were erected, and the weight of the house transferred to them. At the end of the summer lysimeters for catching drainage water were constructed in certain plots, and deep pits were dug and rendered waterproof in adjacent paths for access to the drainage water collecting in bottles.

In the cucumber houses bee screens were found to be essential because of damage suffered by the second crop. These were made and installed by the Technical Services Unit so that accidental pollination of the crop might be prevented in future.

### **Cropping in general**

#### *Tomatoes*

As would be expected on an experimental nursery, yields varied enormously from 7lb. per plant in the "starved" plots of B block to an average of 12lb. per plant for the variety 'Immuna' in the magnesium experiment in houses D1-2.

Tomato Leaf Mould (*Cladosporium fulvum*) caused no trouble, control measures being applied each week in mid-season to prevent it. *Botrytis* needed careful watching, and control measures were frequently used; few plants were lost, however. No Red Spider Mite was seen, but White-fly needed control occasionally. Tomato Mosaic Virus was widespread in mid-season.

#### *Cucumbers*

Two crops were grown. The first yielded an average of 45 fruits per plant in 12 weeks cropping, the second only about 10 fruits per plant before the damage caused by bees took place and recording was stopped.

Cucumber Mildew was prevalent throughout the season. The main control measure was "Karathane" dust.

#### *Carnations*

All three houses were cleared of the first crop, which had been growing for three seasons, and preparations were put in hand for re-stocking throughout with cuttings from wilt-cultured mother stock. As already mentioned, the three houses were separated by glass partitions and

concrete beds were laid in the middle house (E2), which was planted in mid-July. This was for the nutritional experiment run by the Chemistry Department. House E3 was planted up with a collection of varieties in beds made up in the border soil after steam sterilisation. House E1, allocated to the Mycology Department, was only partially planted; a start was made in constructing concrete beds in the remainder of the house.

### *Lettuce*

About 20,000 lettuce were grown for the Plant Breeder before the tomato crop was planted, and a larger programme was undertaken in the autumn with about 60,000 plants, of which some 45,000 were planted out for selection for seed production the following summer.

### *Chrysanthemums*

1,200 pots of November and December flowering varieties were grown, and 12 to 16 disbudded blooms were taken per pot. Tests were made for aspermy virus and all infected plants were burned. The following varieties were added to the collection:

|                      |                         |
|----------------------|-------------------------|
| 'Ron Shoesmith'      | 'Yellow Fred Shoesmith' |
| 'Gordon Wells'       | 'December Red'          |
| 'Crimson Robe'       | 'Balcombe Perfection'   |
| 'Orange Ada Stevens' |                         |

### *Ornamental plants*

Geraniums, Gazanias, Dahlias and certain annuals were propagated for decorative purposes at the Institute. A quantity of *Cupressus macrocarpa* and pines were grown from seed for future plantings along the boundaries.

### **Research glasshouses**

The research or "special purpose" glasshouses comprise three houses each 100ft. by 18ft., two houses each 29½ft. by 10ft., and one house 51ft. by 46ft. These glasshouses, which are constructed of aluminium alloy, were brought into full operation in the spring of the year. A member of the nursery staff was transferred to look after the culture of the plants required by the various research Departments. Some teething troubles were encountered with the oil-fired "packaged" steam boiler which heats this section, and it was not until the end of the year before all was well. The heating system is now functioning reliably, and the steam "on tap" is most convenient for the frequent steam-sterilising operations that are necessary.

### **The mushroom research unit**

This comprises three houses, two of which are new, with a total area of cropping beds of about 2,000 square feet. All three houses are now on the tray system for convenient experimental layouts, but the trays are supported on fixed shelves.

At the beginning of the season the mushroom compost was made of straw decomposed with activators, but at the end of August a change of policy was decided upon, and from then on the compost was made of horse manure. Casing was done with peat and chalk, except where experiments required otherwise.

### **Warning system**

A warning system was designed and installed ready for the 1958/59 season in the two boiler houses, and tests are made once a week. Although the boiler houses are well catered for, the



individual glasshouses have not been added to the system as this would add greatly to its complexity. The warning normally sounds in the Nursery Manager's house, but can be switched to either of the other two cottages in his absence. The system has been well tried already and the occasional night visit to correct faults has been necessary.

### **Reserve land**

The clover crop came on well and was sold as a standing crop for hay, the buyer undertaking the cutting and hay making. A second cut was taken and ploughed in, and the land was ploughed once more before the end of the year prior to being seeded with spring wheat and undersown with a ley mixture.

The area reserved for glasshouse extension in the foreseeable future was levelled and sown to grass. This will be regularly cut with a gang-mower.

### **Wind-breaks**

An additional line of trees to act as a wind-break was planted of *Populus eugenei*. This line runs north-south to the west of the nursery in the hope that its quick growth will provide shelter from the south-westerly gales in five to six years' time. The cuttings were rooted in 1957 and planted in their present position early in 1958 when they were 2½–3ft. tall.

### **Site clearance**

This operation continues, but progress in levelling and cleaning land hitherto occupied by the builders was slow owing to the very wet summer. It is hoped to sow grass on some of the areas next spring.

### **Equipment**

Among major items of equipment obtained during the year were a front loader for the tractor, a manure turner, a pallet truck, a concrete mixer, a set of pipe threading dies, and six thermographs.

## II. GENERAL REVIEW OF RESEARCH WORK

### 1. PLANT PHYSIOLOGY

*by*

**E. R. LEONARD**

The special purpose glasshouse for the Plant Physiology Department was not fully functional by the end of the year. A major alteration to the heating system was the transfer of the expansion tank to the roof of the stairhead to provide additional head of water and thereby obviate admission of air to the hot water system during its temperature cycles. It also avoids the earlier difficulty of the flooding of the underground laboratories when steam to the calorifier is not shut off during a period when the water circulating pump fails, and the water in the calorifier boils. Modulating control of the automatic ventilating system has not been provided, full open or full shut being the only ventilator positions at present available.

Restricted trials of adjustment of the various thermostats in relation to temperature, etc., distribution within the glasshouse under different external conditions are all that have so far been possible, and only a few experimental plants have been placed in it. It is hoped that remedies will be found to provide the environmental conditions required.

Mr. Hack presented a paper to the XVth International Horticultural Congress at Nice on soil moisture tension measurement in glasshouses and its trends in relation to the growth of the aerial parts of the tomato plant. This maintains the sequence of contributions to this Congress from the Plant Physiology Department.

#### **Environmental observations (H. R. B. Hack)**

Methods of measuring the factors of the environment are being developed further and tested. Transducers are placed in the glasshouse or the laboratories according to the test. Electronic potentiometer recorders are employed in all cases for recording the voltage analogue of each climatic variable being measured. These potentiometers are housed together with ancillary equipment in the thermostatted, partly underground laboratories.

Temperature has been measured by thermocouples, and tests have been carried out on apparatus for increasing the number of points which can be measured on the recording potentiometer. Calibrations are carried out in an N.P.L.-designed hot water bath.

Humidity has been measured by wet and dry thermocouples. Tests have been carried out to improve the behaviour of these in slow moving air.

Air speed has been measured by hot-wire anemometers. These have been calibrated by the N.P.L. and re-calibrated after several months' continuous use. The changes in calibration were small.

Solar radiation has been measured by thermopiles (South African model). A sub-standard thermopile periodically re-calibrated at Kew Observatory is maintained for comparison with other instruments. Integration of the potentiometer records is carried out by recording, on a printing counter, the revolutions of a low inertia motor. This motor is driven by a voltage fed

from a transmission slidewire mechanically linked to the potentiometer drive. The revolutions are pulsed by a phototransistor relay system. Good agreement has been obtained between results from the counter and the planimetered area of the potentiometer record.

Work, initiated at Cheshunt, has been resumed on small scale soil moisture tension control using porous ceramic cells, in conjunction with measurement of the soil moisture tension by laboratory type tensiometers and with observation of root growth in glass panels. Marked differences were observed, as the plant increased in size, in the withdrawal of water from different parts of the volume of soil available to the roots.

#### **Growth analysis of the tomato in relation to time of year (A. J. Cooper)**

The long term growth analysis experiment on the effect of time of year in relation to the age of the plant on the growth of the different organs has continued. The large volume of data collected will require a considerable time to analyse.

A further slight improvement in temperature distribution and stability has been obtained in the block of glasshouses in which this work is being carried out by covering over the trench at the south end containing the uninsulated main hot water pipes with concrete slabs, and by placing a small heating lamp bulb below the relatively insensitive rod-type thermostat, to increase its rate of response to changes in air temperature, as recommended by the N.I.A.E. Major improvement is dependent upon the complete re-organization of the heating system of the trial glasshouses.

In collaboration with three other centres, in Scotland, the Midlands and the Channel Isles, the growth analysis experiment was extended to different latitudes, using only two growth criteria.

#### **Effect of inflorescences on growth of axillary shoots (A. J. Cooper)**

A trial was undertaken to investigate the effect of the presence of inflorescences on the main stem of the tomato on the growth of adjacent axillary shoots.

#### **Tomato spacing (A. J. Cooper)**

In an adjacent glasshouse a spacing trial of two different densities of planting was carried out, to determine the higher limit beyond which no increase in crop is obtained. This work was carried out in collaboration with the Nursery Manager, Mr. J. M. Evans.

#### **"Blotchy ripening" (A. J. Cooper and E. R. Leonard)**

At the request of the Research Committee increased attention is being paid to the problem of abnormal pigmentation in ripening tomato fruits. Computation of three years' data from the growth analysis experiments is being undertaken by the Rothamsted Statistics Department, using the electronic computer, to examine the interrelation during development and ripening of the different grades of coloration in relation to hours of bright sunshine and ambient temperature in the glasshouse. Considerable labour is needed to extract the required data (duration of temperature above  $x$  degrees, etc.) from the thermograph records and to relate these to pigmentation changes. For control of the micro-environment around the fruit and for assessment of the colour special equipment is required. Progress will be slow whilst this is being constructed or acquired.



## 2. CHEMISTRY

by

G. W. WINSOR

Investigations during 1958 have again been centred on the nutrition of glasshouse crops and the composition of tomato fruit. Certain changes have, however, been made in the research programme, of which the most important has been the initiation of biochemical studies on the enzyme systems concerned in fruit ripening. The latter programme forms a logical extension of existing studies of the various constituents of tomato fruit, and should ultimately have an important bearing on problems of fruit quality. Studies on plant nutrition have also been extended to include manurial trials with glasshouse carnations. Investigations on the measurement of soil salinity ( $pC$ ), last referred to in the Annual Report for 1956, have now been resumed, but progress in this field was delayed by the occurrence of marked symptoms of manganese toxicity in the test plants (lettuce) when using steam-sterilized soil. It now appears that manganese toxicity is a major problem both at the Institute and elsewhere, and detailed investigation will be necessary. Owing to the demands of other work, studies on the development of urea-formaldehyde compounds as slow-acting nitrogenous fertilizers have been suspended.

### **The composition of tomato fruit (J. N. Davies and G. W. Winsor)**

Studies of the composition of tomato fruit have been continued and extended, the subjects chosen for investigation during 1958 including the following:

- (a) Preliminary studies on the effects of nutritional factors on fruit composition.
- (b) The effects of shading on fruit quality and composition.
- (c) Comparison of the fruit of different varieties of tomato.
- (d) Comparison of hormone-set and naturally pollinated tomatoes.
- (e) The composition of green fruit showing "bronzing".

The methods of analysis of expressed sap developed for the relatively rapid examination of tomato fruit in recent years have again been used, the determinations selected for routine use including titratable acidity, sugars and total soluble solids. In addition it has been possible, for the first time in these investigations, to obtain accompanying data for the sugar content of the fruit samples as determined by extraction with alcohol and also by hot water; determinations of the acidity of both alcoholic and aqueous extracts of the fruit have also been made. The content of vitamin C in tomatoes has been studied in some instances, particularly in regard to variety and to the effects of shading upon the fruit. Further use has been made of methods for the micro-determination of individual sugars after chromatographic separation. In order to obtain more detailed information concerning the acidity of tomato fruit, apparatus for the fractionation of non-volatile acids is under construction and should be in operation early in 1959.

Preliminary studies of the refractive index of the expressed sap of tomato fruit in relation to the concentration of soluble solids were described briefly in the Report for 1957. The small hand refractometer used in this earlier work has since been replaced with a sensitive immersion refractometer with facilities for precise temperature control. Refractometer readings were normally taken on all samples of expressed sap throughout the season. A close relationship was found between refractometer readings and total soluble solids as determined by oven-drying; statistical examination of the data is still incomplete, but one group of 255 samples gave a correlation coefficient of  $+0.973$ , significant at  $P=0.001$ . The increased sensitivity of the new instrument,

as compared with the simple model previously available, greatly enhances the value of this method for the rapid assessment of total solids in expressed fruit juices.

As an alternative to existing methods of expression and analysis of fruit juices, using relatively large samples, procedures for the examination of small samples are being developed, based on the use of the hydraulic press and semi-micro analytical methods. The new procedures are particularly applicable to comparative studies of different portions of individual fruits, and have already been used in preliminary studies of green tomatoes showing "bronzing". The methods should also permit the examination of larger numbers of samples, as will be necessary when studies of fruit composition are extended to include the larger manurial trials now in progress.

*The effect of manurial treatments on the composition of tomato fruit of varieties 'Potentate' and 'Immuna'*

Comparative studies of the composition of fruit of these two varieties, both of which were grown in each of 36 plots in the trials on magnesium deficiency in houses D1 and D2, were described in the Annual Report for 1957. The investigation has now been extended to include the effects of manurial treatment on composition. Four combinations of treatment were selected for each variety as follows:

|                                         |                           |
|-----------------------------------------|---------------------------|
| "Medium" potash                         | No magnesium              |
| "                  "                  " | Magnesium as foliar spray |
| "High" potash                           | No magnesium              |
| "                  "                  " | Magnesium as foliar spray |

Fruit of the best quality available was taken for analysis, a combined sample being obtained from the six replicated plots of each fertilizer treatment on 18 days between June and early October. The methods of analysis used included determinations of sugars, titratable acidity, total solids and refractive index of the expressed sap.

The effect of "high" as compared with "medium" potash was to increase the mean value for titratable acidity of the expressed sap from 6.8 to 7.5 milliequivalents per 100ml. in the case of 'Potentate', and from 7.7 to 8.3 for 'Immuna', the difference being significant at  $P=0.01$  in both cases. These differences in acidity were also reflected in the data for total solids in the sap, but the sugar content of the sap remained unaffected by the level of potash in the soil.

Foliar sprays containing magnesium sulphate had no significant effect on the composition of fruit of variety 'Potentate', but interesting results were obtained with 'Immuna', a variety highly susceptible to magnesium deficiency. Thus treatment with the magnesium salt caused a highly significant increase in the concentrations of sugar and total solids in the expressed sap at the "medium" level of potash, but significantly reduced them at the higher level of soil potash. Some increase in acidity also resulted from the foliar spray applied at the "medium" level of potash. These results are of interest in that the effect of magnesium sprays on fruit composition occurs with a variety particularly prone to show visual symptoms of magnesium deficiency; furthermore the crop records show some improvement in fruit quality from additions of magnesium at the lower level of potash, but little effect at the "high" potash level. On the basis of these results it seems evident that studies of fruit composition can contribute to the results of nutritional experiments, and should be extended to include the main manurial trials now in progress with tomatoes.

Comparison of the composition of fruit of the two varieties gave results similar to those reported in 1957. Thus fruit of the variety 'Immuna' was more acid than that of 'Potentate', but the mean values for sugars in the sap were almost identical.

### *The effect of shading on fruit composition*

Observations in the course of earlier studies of fruit composition led to the suggestion that light was a factor having considerable influence, either directly or indirectly, on the proportions of certain constituents of tomato fruit. Arrangements were therefore made to study the effects of shading on the composition of tomatoes, the work being combined with other studies on the effect of light on total nutrient uptake by tomato plants.

In the absence of more specialised facilities, the effect of exposure to light was examined by comparison of shaded and unshaded plants. Shading was provided by frameworks of wooden slats. In order to provide adequate replication with the minimum of interaction between treatments, the experimental plants (pot-grown) were carried in pairs on movable trolleys, six trolleys being permanently shaded and six fully exposed; the positions of the trolleys within the glasshouse were re-arranged at random at frequent intervals throughout the season.

The plants were stopped at the fifth truss. Crop yields and visual grading of the fruit were recorded on the basis of separate trusses of individual plants. The fruit used for analytical studies was of the best quality available, composite samples being taken on two separate occasions to represent each of the five trusses.

The analytical results include data for total solids, sugars and titratable acidity in the expressed sap, and sugars and acids as extracted from the fruit by 80% ethyl alcohol and also by hot water. Determinations of dry matter and vitamin C content were also made. The data in Table I illustrate some of the main effects observed in the first year of the experiment.

TABLE I  
THE COMPOSITION OF TOMATOES FROM SHADED  
AND UNSHADED PLANTS (VARIETY: 'POTENTATE')

|                                                | Unshaded<br>plants | Shaded<br>plants | Significant differences<br>between means |        |
|------------------------------------------------|--------------------|------------------|------------------------------------------|--------|
|                                                |                    |                  | P=0.05                                   | P=0.01 |
| Sugars in the expressed sap (g./100 ml.)       | 3.43               | 2.51             | 0.29                                     | 0.48   |
| Titratable acidity of the sap*                 | 4.0                | 6.0              | 0.4                                      | 0.6    |
| Total solids in the expressed sap (g./100 ml.) | 4.27               | 3.73             | 0.31                                     | 0.51   |
| Sugar content of the fresh fruit (%)           | 3.12               | 2.31             | 0.29                                     | 0.48   |

\*Milliequivalents of acid per 100 ml. of sap.

The results in Table I show that the sugar content of the fruit was markedly reduced by shading. A decrease in photosynthetic activity would be expected from shading the plants, and the present results illustrate the way in which this can affect fruit composition. Even more interesting is the effect of shading on the acidity of the fruit, this being higher for the shaded than for the unshaded plants. The data for acidity of the expressed sap in Table I are also supported by results (not shown) for free and total acids in the alcoholic and hot water extracts.

The mean yields of fruit per plant, obtained from five trusses, were 3,408 and 1,816g. in the exposed and shaded series respectively; the mean weight per fruit was also decreased by shading. Examination of the extensive crop records is still incomplete, but two general conclusions are already apparent. Thus the proportions of fruit showing uniform pigmentation and regular or not too irregular shape (grades A and B respectively as defined in connection with the manurial



trials) were markedly higher in the shaded plants, accompanied by a decrease in the percentage of fruit showing irregular colour in any form (grade C). Striking differences were also found in the sub-division of non-uniformly coloured fruit into various subsidiary categories. Thus 57% of the total crop from plants exposed to full sunlight showed yellow or yellow-orange areas (usually hard and inedible) near the calyx, as compared with under 4% from the shaded plants. The effects of light and shade on other abnormalities of pigmentation, including those more typically included under the ill-defined term "blotchy ripening", are less readily apparent from the data so far available, and discussion will be deferred until the experiment has been repeated.

#### *The composition of fruit of different varieties of tomato*

The following eight varieties were grown in house C1 for comparative studies of the composition of different varieties of tomato:

- |                  |                 |
|------------------|-----------------|
| A. 'Ailsa Craig' | E. 'Delicious'  |
| B. 'Moneymaker'  | F. 'Potentate'  |
| C. 'L.M.R.1'     | G. 'Ware Cross' |
| D. 'Radio'       | H. 'E.S.5'      |

The experimental plants occupied 48 plots arranged in six randomized blocks, each plot containing 8 plants. Samples of the best quality fruit available from each variety were collected for analysis of the expressed sap on 19 occasions from June to September. At 10 of these sampling dates additional material was preserved in alcohol and also extracted with hot water for the determination of sugars and acids; results for the alcohol-preserved fruit are as yet incomplete, and will be omitted from the present discussion.

Crop yields and grading of the fruit are recorded in Table II, together with mean analytical values for the fruit of the 8 varieties during the season. An early outbreak of virus occurred among plants of the variety 'E.S.5' towards the south end of the house, and it subsequently proved difficult to prevent severe wilting of the plants in bright sunny periods, except at the north end of the house. Crop yields for the two northern blocks in the house have accordingly been shown separately in the Table, together with the mean values for all six blocks; in both sets of data the heaviest yields were given by 'Radio', 'Delicious' and 'Ware Cross', and the lowest yields by 'Moneymaker' and 'L.M.R.1'. 'Potentate' proved to be the variety most sensitive to the less favourable growing conditions in the central and southern blocks. Marked differences were found in the grading of the fruit, particularly in the relative proportions of grade A (uniform colour, regular shape) and grade B (uniform colour, somewhat less regular shape); in this respect varieties 'Ailsa Craig' and 'L.M.R.1' were outstandingly good, whilst 'Potentate' displayed its characteristic irregularity of shape.

Fruit of 'Ailsa Craig' and 'E.S.5' showed the highest content of sugars and total solids in the expressed sap. Varieties 'L.M.R.1' and 'Ailsa Craig' gave the highest acidity in the fruit juices, and 'Potentate' and 'Radio' the lowest. Statistical analysis of the data for expressed fruit juices shows highly significant differences between varieties in all three tests; the widest range of variation, however, is found in the acidity of the fruit. The ratio of acids to sugar also shows interesting trends, the highest value being for variety 'L.M.R.1' and the lowest for 'Potentate'; these two varieties also appear to represent the extremes of flavour encountered in this series of trials.

TABLE II

CROP YIELDS, GRADING AND MEAN ANALYTICAL DATA FOR 8 VARIETIES OF TOMATO

|                                                                                | 'Ailsa Craig' | 'Moneymaker' | 'L.M.R. 1' | 'Radio' | 'Delicious' | 'Potentate' | 'Ware Cross' | 'E.S.5' | Significant differences |        |
|--------------------------------------------------------------------------------|---------------|--------------|------------|---------|-------------|-------------|--------------|---------|-------------------------|--------|
|                                                                                |               |              |            |         |             |             |              |         | P=0.05                  | P=0.01 |
| Yield ( <i>lb./plant</i> ) based on two replications at north end of the house | 10.1          | 8.7          | 8.8        | 11.9    | 11.3        | 10.7        | 11.3         | 10.0    | —                       | —      |
| Yield ( <i>lb./plant</i> ) mean of all six replications                        | 8.4           | 7.6          | 7.7        | 10.4    | 9.2         | 7.8         | 9.2          | 8.3     | 1.1                     | 1.5    |
| Grade A fruit (%)                                                              | 67            | 57           | 67         | 51      | 47          | 32          | 46           | 63      | —                       | —      |
| " B " (%)                                                                      | 14            | 29           | 15         | 19      | 22          | 35          | 26           | 20      | —                       | —      |
| " C " (%)                                                                      | 18            | 14           | 18         | 29      | 30          | 26          | 25           | 16      | —                       | —      |
| Total solids in sap (g./100 ml.)                                               | 5.46          | 4.91         | 4.97       | 4.63    | 4.71        | 5.01        | 4.72         | 5.16    | 0.20                    | 0.26   |
| Sugars in sap (g./100 ml.)                                                     | 3.50          | 3.23         | 3.01       | 2.99    | 2.93        | 3.34        | 3.05         | 3.48    | 0.18                    | 0.23   |
| Titratable acidity (milli-equivalents/100 ml.)                                 | 10.3          | 8.8          | 10.8       | 8.0     | 9.0         | 7.9         | 8.3          | 8.6     | 0.4                     | 0.5    |
| Acidity/sugar ratio of expressed sap                                           | 2.9           | 2.7          | 3.6        | 2.7     | 3.1         | 2.4         | 2.7          | 2.5     | —                       | —      |
| Sugars extracted by hot water (g./100 g. fresh fruit)                          | 3.22          | 3.22         | 3.03       | 2.95    | 2.99        | 3.34        | 2.80         | 3.30    | 0.24                    | 0.31   |
| Free acids extracted by hot water (milliequivalents/100 g.)                    | 9.2           | 7.6          | 9.1        | 6.8     | 8.0         | 7.2         | 7.1          | 7.2     | 0.5                     | 0.7    |
| Total acids extracted by hot water (milliequivalents/100 g.)                   | 17.7          | 15.1         | 17.2       | 14.2    | 15.9        | 15.3        | 15.2         | 15.1    | 1.2                     | 1.6    |
| Vitamin C (mg./100 g. fresh fruit)                                             | 16.3          | 15.1         | 14.3       | 10.7    | 14.7        | 13.1        | 12.9         | 13.8    | 2.0                     | 2.6    |
| Dry matter in fruit (%)                                                        | 7.40          | 6.79         | 7.16       | 6.31    | 6.85        | 6.88        | 6.53         | 6.90    | 0.36                    | 0.43   |

Interesting seasonal trends in the composition of the expressed sap were again noted. Thus the concentrations of sugars and total solids gradually rose to a maximum in early August, whereas titratable acidity reached the maximum by mid-July and decreased subsequently to the lowest values of the season.

Values for sugars and acids determined in hot water extracts of fresh tomatoes show a clear general relationship to results obtained for the expressed sap of frozen fruit, though minor deviations do occur. It should be stressed, however, that the results of analyses of the sap and of hot water extracts are of necessity expressed on entirely different bases, and that the mean data in Table II refer to different combinations of sampling dates. The values for total acidity of the hot water extracts were obtained by titration after passage through a cation-exchange resin (Zeo-Karb 215).

Significant differences were found among the mean values for vitamin C in fruit of the eight varieties grown. A seasonal trend was also apparent, the content of vitamin C increasing to a maximum in August and early September, as previously noted for the sugars of tomato fruit.

#### *Studies of the carbohydrates in tomato fruit*

Changes in the concentration of reducing sugars in the expressed sap of tomato fruit during ripening have been described in previous Reports, the sugar content of the sap increasing from the mature green to the red stages of pigmentation. It has now been shown that the percentage of reducing sugars in tomato fruit, as determined in alcoholic extracts of the fresh fruit, follows a similar trend in both fruit walls and whole fruit.

The concentrations of glucose and of fructose were studied by chromatographic separation on paper followed by colorimetric estimation, as previously reported (1). The sum of glucose and fructose thus determined was in close agreement with values obtained by the volumetric method in general use in this Department (6), and no other free sugars were detected in the fruit.

From the data so far available it appears that glucose and fructose are present in the fruit in approximately equal proportions. Studies of immature green fruit of variety 'Potentate' at four stages of development have, however, shown a slight excess of glucose, the glucose/fructose ratio ranging from 1.06 to 1.11. The latter ratio decreases as ripening proceeds; thus recent analyses have shown glucose/fructose ratios of 0.85–0.98 for ripening fruit of variety 'Potentate', and still lower values (0.70–0.80) for fruit of variety 'E.S.5'.

Limited numbers of "blotchy" and "waxy" fruit have also been examined. It appears that, despite the much lower concentrations of glucose and fructose in poor quality fruit, the ratio of these two sugars does not differ very markedly from that found in the corresponding samples of normal fruit, though work on this subject is still incomplete.

#### **Pectic enzymes in tomato fruit** (G. E. Hobson)

Studies of enzymatic transformations in tomato fruit were commenced in 1958, beginning with those enzymes responsible for changes in the pectic constituents during ripening. It seemed likely that the activities of the pectic enzymes were intimately associated with the softening of the tissues which accompanies ripening, and hence that studies of these enzymes would contribute to our knowledge of normal and abnormal ripening processes in tomato fruit.

The pectic enzymes present in tomato fruit may, for convenience, be grouped under three main headings, namely:



- (i) protopectinase, which converts protopectin into soluble pectin,
- (ii) pectin methylesterase, converting pectin into pectic acid and methyl alcohol, and
- (iii) pectin-polygalacturonase, which causes a progressive reduction in the molecular size of the pectic acid.

Of these enzymes, pectin methylesterase was selected for initial study, the primary object being to establish a relationship between colour, firmness, enzyme activity and the proportion of the total pectic substances present in soluble form during the normal processes of ripening. The selection of fruit for these studies at five different stages of ripeness, based on external colour, is described in detail in a separate article in this Report, together with a method for measuring the firmness of tomatoes on an arbitrary but reproducible basis.

Total and soluble pectin were determined by the titrimetric procedure of Doesburg (2). Pectin methylesterase activity was determined by the electro-metric titration procedure of Kertesz (3). Extraction of the enzyme from macerated tomato fruit was based on the general methods of Pithawala *et al.* (5); the sodium phosphate extractant recommended proved undesirable in the subsequent estimation of enzyme activity, however, and after considerable exploratory work was replaced by 0.5 M-sodium acetate at pH 8.0.

The fruit samples studied during 1958 included nine graded series of variety 'Potentate' and four series of variety 'Immuna'. Some aspects of the analytical work still await completion, but the results may tentatively be summarized as follows. Pectin methylesterase activity increased progressively from green to red fruit (Table III), as did the proportions of the total pectic substances present in soluble form. These changes were accompanied by marked softening of the fruit, as shown by increasing ease of compression in the testing apparatus (see separate article). No significant changes could be demonstrated in the total pectic content of the fruit during ripening.

TABLE III  
PECTIN METHYLESTERASE ACTIVITY\* IN TOMATO  
FRUIT AT FIVE STAGES OF RIPENESS

| Colour of fruit | Variety     |          |
|-----------------|-------------|----------|
|                 | 'Potentate' | 'Immuna' |
| Green           | 3.1         | 4.3      |
| Green-orange    | 3.8         | 6.1      |
| Orange-green    | 4.1         | 7.5      |
| Orange          | 4.6         | 8.3      |
| Red             | 4.6         | 8.4      |

\*The unit of activity is here defined as the quantity of enzyme which would liberate 32mg. of methyl alcohol from pectin in 1 minute at 27°C. in 0.05 M-sodium acetate at pH 7.5, and is expressed on the basis of 100 g. fresh fruit.

Apart from changes in enzyme activity occurring during the ripening of tomato fruit, several other features of interest have arisen in the course of these studies. Thus the results in Table III show higher enzyme activity for fruit of variety 'Immuna' than for 'Potentate'; the latter variety was in fact found to ripen more slowly than 'Immuna'. Exploratory tests also showed lower methylesterase activity in the green than in the red areas of irregularly coloured tomato fruit, though further tests will be necessary before this conclusion can be regarded as fully established.

The effects of plant nutrition on pectin methylesterase activity, and the influence of enzyme concentration upon fruit quality, are under consideration.

#### **Phosphate in soils and plant nutrition (D. M. Massey)**

The extremely low levels of "available" phosphate encountered during calibration trials (1954-6) in the newly constructed glasshouses on this site led to further examination of methods for the assessment of phosphate in soils, and also to studies of the response of tomato plants to various levels of added phosphorus.

The preliminary phase of these investigations was an observational trial with tomato plants grown in soil taken from under grass between the glasshouses; this soil approximates closely to conditions in the new glasshouses when calibration trials were first started. Tomato seedlings transplanted at an early stage into 10in. pots of this soil, to which nitrogen and potash were added, rapidly developed a dark purple-green colour and made little growth at first, though some improvement occurred as the trials continued. Addition of superphosphate at 3oz. per bushel largely eliminated the symptoms, and at 9oz. per bushel growth was normal. In the absence of added phosphate, liming the soil accentuated the deficiency symptoms, as was also the case at the lower level of added phosphate. Similar effects were obtained with subsoil from the same site.

These results throw considerable light on the calibration trials in preceding years, where phosphate deficiency had been suspected but received no support from tissue analyses in mid-season. It has now been established that phosphate deficiency has a very marked effect on the growth of young tomato plants in soil from this site, but as growth continues and a more extensive root system develops the effects of the deficiency are partially overcome. The adverse effect of liming on phosphate deficiency, as noted in these pot experiments, was subsequently confirmed in the first year of the factorial manurial trials in B block (see later).

For comparison with the acid extractant (0.5N-acetic acid) normally employed in the estimation of "available" phosphate in these laboratories, the use of an ion-exchange material, sodium zeolite (4), was investigated; the latter technique is based on exchange between the sodium ions on the zeolite and the calcium of the relatively insoluble phosphates present in the soil, and is a far less drastic treatment than extraction with acids. Both methods of extraction were applied to samples of the Institute field soil as used in the previous trial, and to the soil at 15 different levels of added superphosphate. Somewhat more phosphate was extracted by acetic acid than by the ion-exchange procedure, but the results from the two methods showed a rather similar relationship to the growth of tomato plants in pot experiments with the treated soils; the mathematical aspects of this relationship need further examination, but additions of superphosphate in excess of those required to give about 0.045% of phosphate ( $P_2O_5$ ) extractable at the end of the trials by 0.5N-acetic acid, or 0.035% by the ion-exchange procedure, gave little or no further increase in fresh weight of the plants. The total fresh weight of tomato plants grown for 35 days in the field soil without added phosphate was only 13% of the maximum obtained in the treated soil.

Further trials with various levels of added inorganic phosphates confirmed that both the extraction procedures tested gave satisfactory relationships with crop growth in pot trials, thus suggesting little need for replacing the more convenient acid extraction procedure. When soil treated with steamed bone flour was analysed, however, surprising differences in "available" phosphate were recorded by the two procedures, and growth trials suggested that the acid extractant was giving misleading results. The latter discrepancy will be investigated further in view of the use of bone products in horticulture.

### **Soluble salts in glasshouse soils (D. M. Massey and G. W. Winsor)**

A critical re-examination of the methods available for the estimation of soluble salts in soil was published in the Annual Report for 1956 (7), it being concluded that the conventional procedure used in this country was unreliable in the presence of high concentrations of calcium sulphate such as are commonly encountered in old glasshouse soils. Further studies on this problem were started in the early autumn of 1958. Unforeseen cultural difficulties occurred, however, when attempting to continue research on the effects of fertilizers and of calcium sulphate on the growth of lettuce plants in steamed soil, many of the plants showing severe marginal chlorosis and necrosis. Further progress was impossible until the cause of the trouble, similar to that encountered on the main nursery during the winter, could be ascertained and remedied. The possibility of manganese toxicity is now being examined. It has already been established that partial sterilization considerably reduces the growth of lettuce in the soil used for these trials, but that liming after steaming improves growth considerably.

Studies on the determination of soluble salts will be resumed as soon as possible, the primary object being to re-establish the use of conductometric methods on a more reliable basis than before; such methods are now urgently needed in connection with nutritional trials at this Institute, apart from their wider application in advisory work.

### **Manurial trials with glasshouse crops (G. W. Winsor, M. I. E. Long and J. N. Davies)**

The programme of nutritional studies on tomatoes has been continued and extended, and in addition a new series of studies on the nutrition of carnations has been initiated. Trials with tomatoes include both solid and liquid feeding, whilst for carnations the application of fertilizers, other than those supplied in the original compost, is at present confined to liquid feeding. A summary of progress in the various experiments is given under separate headings. The basic scheme of visual grading of tomato fruit from the manurial trials, applied to all plots or sub-plots, was as follows:

- Grade A. Fruit of uniform colour and shape.
- Grade B. Fruit of uniform colour but of rather less regular shape than grade A.
- Grade C. Fruit showing irregular coloration of any kind, sub-divided on the basis of severity into:
  - Sub-grade 1. Slight to moderate severity.
  - Sub-grade 2. Severely affected.
- Grade D. Any fruit not included in grades A–C, primarily consisting of fruit of highly irregular shape.

### **$3^2 \times 2^3$ factorial nutritional trial with tomatoes (Block B)**

The object of this long-term experiment is to study the main effects and interactions of four macro-nutrients, each at two levels of liming, on a more extensive scale than has hitherto been possible. The trial was started in 1958, following constructional work in the houses during the winter months. This block of glasshouses had previously been included in calibration trials without addition of fertilizers for three years, and later cropped for one season at low nutrient levels. The soil had never been steamed, and results subsequently obtained in 1958 indicated that such treatment was overdue. Preparations for the trial included sub-division of the block to give 112 plots, separated by brick walls to a depth of 3ft. in the soil, each plot having an area of 4.35 sq. yd. As a result of this sub-division of plots an effective experimental layout has been achieved in which it will be possible to maintain the various levels of soil nutrients without the



uncertainty normally associated with cultural operations such as steaming, flooding and digging. At present all 40 plots adjoining the outside of the block are being left as guard plots, entirely enclosing the inner 72 plots in which the present phase of the manurial trials is being conducted.

Manurial treatments included three levels of nitrogen and of potassium, and two levels each (presence and absence) of added phosphorus, magnesium and lime. All nutrients were given in solid form, applied in both the first and second spits in order to extend the zone in which differences in nutrient level occurred in the first year of the trial. Top-dressings of nitrogen, potassium and magnesium were given at intervals through the growing season. The total amounts of nutrient applied in base and top dressings during 1958 were as follows:

|            |            |                                                      |
|------------|------------|------------------------------------------------------|
| Nitrogen   | <i>N1</i>  | Nil                                                  |
|            | <i>N2</i>  | 1oz. nitrogen per sq. yd.                            |
|            | <i>N3</i>  | 2.5oz. nitrogen per sq. yd.                          |
| Potassium  | <i>K1</i>  | Nil                                                  |
|            | <i>K2</i>  | 8oz. sulphate of potash per sq. yd.                  |
|            | <i>K3</i>  | 1lb. sulphate of potash per sq. yd.                  |
| Phosphorus | <i>P1</i>  | Nil                                                  |
|            | <i>P2</i>  | 8oz. triple superphosphate per sq. yd.               |
| Magnesium  | <i>Mg1</i> | Nil                                                  |
|            | <i>Mg2</i> | 1lb. magnesium sulphate per sq. yd.                  |
| Lime       | <i>Ca1</i> | Nil                                                  |
|            | <i>Ca2</i> | 4lb. ground chalk per sq. yd. (half in second spit). |

The manurial levels chosen for the first year of the trials were intended to establish certain differences in nutrient concentration from the start, particularly in the case of lime and phosphate, and will of course be modified in subsequent seasons.

Each plot contained 16 plants of variety 'Potentate', set out in the houses on April 3rd (planting having been delayed by constructional work and other factors). Watering was uniform throughout the experimental plots and recorded by meter. Picking commenced in early June and was continued to October 16th. Fruit from all plots was recorded separately, graded into five categories as already defined.

A very rapid response to the level of soil phosphorus was observed, it being easy to distinguish visually between P1 and P2 plots within 10–14 days of setting out the plants in the borders. Thus plants at the lower level of phosphorus became very dark green, frequently with purple or purple-brown tinting, and made slower growth initially; the effects of phosphorus deficiency were made worse by liming. The contrast between treatments P1 and P2 diminished as growth continued and the root systems became more extensive, but periodic visual assessment of colour showed discernible differences persisting throughout the season.

Slight differences in colour of the foliage, related to the levels of nitrogen supplied, began to show within 3–4 weeks after planting, and subsequently became increasingly prominent. The height of the plants was not significantly affected by differences in nitrogen level, however, and any trend was towards maximum mean height in the absence of added nitrogen (N1).

Symptoms of magnesium deficiency became widespread in mid-season, but little response to the application of magnesium in base and top dressings was observed in this respect. The records indicate that marked instances of magnesium deficiency were normally associated with medium

or high potash levels (K3 or K2 rather than K1), and that plants grown at low levels of phosphate (P1) were less susceptible, the foliage tending to remain dark green down to the base of the plants.

Visual symptoms of potassium deficiency were limited to individual plants in some but not all plots from which this nutrient was omitted (K1 level); recognition of the characteristic deficiency pattern was, however, greatly obscured by the widespread occurrence of magnesium deficiency.

Soil samples for analysis were taken from all 72 experimental plots on four occasions during the season; the analytical studies are not yet completed, but the mean values which follow, based mainly on samples taken in June, indicate the general pattern:

|                                    |            |            |            |
|------------------------------------|------------|------------|------------|
| <i>Potassium levels</i>            | <i>K1</i>  | <i>K2</i>  | <i>K3</i>  |
| "Available" potash ( $K_2O$ )      | 0.012%     | 0.031%     | 0.060%     |
| <i>Phosphorus levels</i>           | <i>P1</i>  | <i>P2</i>  |            |
| "Available" phosphate ( $P_2O_5$ ) | 0.007%     | 0.031%     |            |
| <i>Nitrogen levels</i>             | <i>N1</i>  | <i>N2</i>  | <i>N3</i>  |
| Nitrate-nitrogen                   | 10 p.p.m.  | 68 p.p.m.  | 134 p.p.m. |
| <i>Liming levels</i>               | <i>Ca1</i> | <i>Ca2</i> |            |
| pH (in May)                        | 6.9        | 7.5        |            |

The mean yields of ripened fruit per plant from the various plots ranged from 4.6 to 11.0lb. according to the treatment combinations applied. The most favourable combinations of treatments included nitrogen and potash at levels 2 or 3 in the presence of phosphate (P2), absence of lime (Ca1) and irrespective of magnesium levels (mean yield for 4 plots=10.1lb. per plant). The main effects of the treatments on crop yield (lb. per plant) are shown in the following data; values for nitrogen and potash are each based on the results for 24 plots, the remaining values being for 36 plots:

|            |      |            |      |
|------------|------|------------|------|
| <i>N1</i>  | 7.83 | <i>K1</i>  | 7.71 |
| <i>N2</i>  | 7.79 | <i>K2</i>  | 7.78 |
| <i>N3</i>  | 7.14 | <i>K3</i>  | 7.25 |
| <i>Mg1</i> | 7.65 | <i>P1</i>  | 6.75 |
| <i>Mg2</i> | 7.52 | <i>P2</i>  | 8.40 |
|            |      | <i>Ca1</i> | 8.08 |
|            |      | <i>Ca2</i> | 7.08 |

It should be emphasized that these are mean values including both favourable and unfavourable combinations of treatments, and hence do not represent the maximum yields attainable at a given level of any one factor.

The most marked effect on crop yields was associated with the level of soil phosphate, the increase resulting from application of this nutrient being significant at  $P=0.001$ . In contrast, the addition of lime significantly decreased crop yields ( $P=0.01$ ). Neither nitrogen nor potash fertilisers significantly affected total crop yields, though in each case the trend was towards a reduction in yield at the highest level of application. Magnesium sulphate applied to the soil had no effect on yields.

A striking relationship was found between total crop yields for the season and the heights of the plants as measured in June.

With regard to fruit quality, four of the five factors included in the trial had significant effects on the proportion of fruit showing uneven ripening. Thus potash applied at the highest level (K3) resulted in only 16% of non-uniformly coloured fruit as compared with 38% at the K1 level (significant at  $P=0.001$ ). Similarly, additions of nitrogen and magnesium reduced the proportions of irregularly coloured fruit, the effects being significant at  $P=0.001$  and  $0.05$  respectively. Addition of phosphate had the reverse effect, the proportion of fruit showing irregular pigmentation increasing from 21% at the P1 level to 27% at the P2 level. Significant interactions with regard to fruit quality were found between nitrogen and magnesium levels, and also between phosphate and potash levels.

Analysis of soil and tissue samples from this trial is still incomplete, and much work remains to be done in relating the analytical results to crop yields and fruit grading. It is encouraging to note, however, that all five factors included in the trial have shown a response in either crop weight or fruit grading within the first season. The layout of the experiment will remain unchanged until all the main conclusions have been fully established.

*The effects of nutrient concentration in liquid feeds on crop yields and fruit quality of tomatoes (House C3)*

This trial was started in 1957, and an account of its layout is given in the Report for that year, together with the results obtained during the first cropping season. In this trial a nutrient solution containing nitrogen and potash ( $K_2O/N=1.75$ ) is applied at four different concentrations, each treatment being replicated four times. Phosphate is applied uniformly throughout as a base dressing. The composition of the nutrient solutions remains unchanged throughout the season, and all water applied other than as overhead damping contains the following nutrients:

|             |  | Nitrogen   | Potash ( $K_2O$ ) |
|-------------|--|------------|-------------------|
| Treatment A |  | 75 p.p.m.  | 131 p.p.m.        |
| „ B         |  | 150 p.p.m. | 263 p.p.m.        |
| „ C         |  | 225 p.p.m. | 394 p.p.m.        |
| „ D         |  | 300 p.p.m. | 525 p.p.m.        |

Application is by hose watering through an automatic pump-operated dilution system. The variety of tomato planted in 1958 was 'Potentate', and nitrogen and potash were entirely omitted from the base dressings; with these exceptions the trial was conducted as already described for 1957.

The house was planted on March 14th, picking started at the end of May and continued until October 1st. All plots received the diluted nutrient solution in equal quantities, the total for the season amounting to 35 gallons per plant. Despite this quite liberal watering and special attention to over-head damping, difficulty was encountered in keeping the plants from wilting in sunny weather; the general appearance of the plants was not fully satisfactory, and suggested the need for steaming the borders before the following season.

Soil and leaf samples were collected periodically during the season and stored for analysis subsequently. This analytical work is as yet incomplete, but determinations of nitrate made on the fresh soil samples gave the following mean values:

| Treatment | Nitrogen in<br>nutrient solution | Nitrate-nitrogen<br>in the soil |            |
|-----------|----------------------------------|---------------------------------|------------|
|           |                                  | May 20th                        | July 10th  |
| A         | 75 p.p.m.                        | 75 p.p.m.                       | 71 p.p.m.  |
| B         | 150 p.p.m.                       | 99 p.p.m.                       | 115 p.p.m. |
| C         | 225 p.p.m.                       | 131 p.p.m.                      | 162 p.p.m. |
| D         | 300 p.p.m.                       | 190 p.p.m.                      | 207 p.p.m. |



Visual assessment of the incidence of symptoms of magnesium deficiency showed the latter to be far less evident at the lowest concentration of nutrients (treatment A). Plants receiving treatment A also showed less vigorous growth, and had a lower average height as measured in July. The yields of fruit were recorded and graded separately for each plot. The mean total weights of ripened fruit were 8.18, 8.59, 8.06 and 7.72lb. per plant for treatments A-D respectively. Yields thus increased from treatments A to B and decreased subsequently with increasing nutrient concentration; the differences in yield between treatments were not statistically significant, however.

The concentration of nutrients in the liquid feeds had a marked effect on fruit quality as assessed by visual grading. Mean values for certain grades and combinations of grades, expressed as percentages of the total ripe fruit, are shown in Table IV.

TABLE IV  
THE GRADING OF FRUIT FROM PLANTS GROWN AT DIFFERENT  
NUTRIENT CONCENTRATIONS IN THE LIQUID FEED

| Treatment                          | Concentration (p.p.m.)<br>in diluted feed |        | Grading of fruit (%) |       |      |
|------------------------------------|-------------------------------------------|--------|----------------------|-------|------|
|                                    | Nitrogen                                  | Potash | A                    | C1+C2 | C2   |
| A                                  | 75                                        | 131    | 26.2                 | 38.1  | 10.2 |
| B                                  | 150                                       | 263    | 40.4                 | 19.2  | 2.1  |
| C                                  | 225                                       | 394    | 47.5                 | 14.9  | 1.1  |
| D                                  | 300                                       | 525    | 47.6                 | 13.3  | 0.5  |
| Significant difference at $P=0.05$ |                                           |        | 5.5                  | 4.9   | 2.9  |
| ,, ,, $P=0.01$                     |                                           |        | 7.9                  | 7.0   | 4.2  |

The results in Table IV show that the proportions of regularly shaped and coloured fruit (grade A) increased with increasing nutrient concentrations in the solutions, accompanied by a marked decrease in the percentage of fruit showing irregular pigmentation (C1+C2); in each grade the effect was most marked between treatments A and B, the trends continuing with further increases in nutrient concentration but to a lesser degree. The most striking feature of these results is found in the percentages of grade C2, representing the most severe instances of irregular pigmentation; this category includes fruit showing well-marked green or yellow-green areas, all fruit in which damage associated with the vascular strands was apparent in the outer walls, and any fruit showing colourless or "waxy" areas. The decrease from 10% to 2% of grade C2 fruit on passing from treatment A to B is particularly striking.

Analyses of soil and tissue samples collected during 1958 are as yet incomplete; results for the leaf samples are essential to any discussion of the relative magnitudes of the chemical (i.e., nutritional) and physical effects of the various treatments. The ultimate aim of the soil analyses must be to relate the data for fruit quality to the concentrations of soluble salts in the soil rather than to those in the nutrient solutions applied; progress in this field has been retarded by the now obvious failings of the conventional  $pC$  test (7) and the consequent need for adopting a more satisfactory procedure. The results from this experiment in 1958 do, however, confirm those obtained in the first year of the trial; nutrient concentrations have a marked effect on fruit quality as assessed by visual grading.

### *Studies on potash/nitrogen ratio in nutrient solutions (House C4)*

Studies on the liquid feeding of tomatoes, using trickle irrigation equipment, were started in this house during 1957. The present experiment provides a comparison of nutrient solutions having four different potash/nitrogen ratios ( $K_2O/N$ ), the ratios selected being 1.0:1, 1.5:1, 2.0:1 and 2.5:1. Details of the experimental layout were given in the Report for 1957 and need not be repeated here in any detail.

In 1958 the nutrient solutions were applied at a concentration of 200 p.p.m. nitrogen in all treatments from the start of the experiment on March 14th, this being reduced to 150 p.p.m. nitrogen throughout from May 13th onwards. A total of 33.6 gallons of diluted nutrient solution was applied per plant during the season. Plant growth was somewhat less vigorous than in the previous year of the experiment, again suggesting the need for steam sterilization.

Records of the incidence and severity of magnesium deficiency symptoms show that the degree of chlorosis was lowest at a potash/nitrogen ratio of 1:1, and increased somewhat with the concentration of potash in the nutrient solution.

Fruit from each of the 24 experimental plots was recorded separately throughout the season until October 1st. The mean yields per plant of ripened fruit decreased progressively with increasing potash/nitrogen ratio from 10.3 to 9.6 lb. per plant; statistical examination of the data shows that the yields obtained at potash/nitrogen ratios of 2.0 and 2.5:1 were significantly lower than at 1:1.

All fruit from the experimental plots was graded as previously described. The results show a highly significant increase in the proportion of grade A fruit (regular shape and colour) with increasing potash/nitrogen ratio, the numerical values ranging from 22.4% at a ratio of 1:1 to 37.2% at 2.5:1. The proportion of high grade fruit was distinctly greater than in the preceding year of the trial. The percentages of fruit showing irregular colour, both in the mild (grade C1) and severe (grade C2) categories, showed a highly significant decrease with increasing potash/nitrogen ratio. The results not only confirm the trends established in 1957 but also show a more marked response to the various treatments than before.

Soil samples were taken from all 24 plots at the end of the season for further study of the distribution of nutrients at and between the nozzles. The analytical data are incomplete at the time of writing, but it has already been confirmed that the highest concentrations of soluble salts occur midway between the nozzles along the lines of the plants, whereas the highest degree of acidity is found adjacent to the trickle nozzles themselves.

Studies of nutrient uptake by tomato plants receiving the four fertilizer treatments were continued as in 1957, all the plant material, including fruit, being collected from 24 plants and stored for subsequent analysis.

### *Magnesium in the nutrition of glasshouse tomatoes (Houses D1 and D2)*

The purpose of this trial is to study the effects of magnesium sulphate, applied to the soil or to the foliage, on (i) visual symptoms of magnesium deficiency, (ii) uptake of magnesium by the plants, (iii) crop yields and (iv) fruit quality. The experiment also includes two levels of potash in the soil in order to provide data on the possible interaction of magnesium and potassium in the nutrition of the crop. The full range of treatments is as follows:

| <i>Treatment</i> | <i>Potash</i> | <i>Magnesium</i> |
|------------------|---------------|------------------|
| A                | "Medium"      | None added       |
| B                | "             | Soil application |
| C                | "             | Foliar spray     |
| D                | "High"        | None added       |
| E                | "             | Soil application |
| F                | "             | Foliar spray     |

The six treatments are each replicated six times, and each plot contains two varieties of tomato ('Potentate' and 'Immuna'), making 72 sub-plots in all. The layout of the trial has already been outlined in the Annual Report for 1957, together with the results obtained in the first season; the trial was continued in the same form for a second season during 1958.

All fertiliser treatments other than those with potassium and magnesium were applied uniformly throughout the houses. For treatments B and E a total of 12oz. per sq. yd. of magnesium sulphate was given in base and top dressings. Foliar sprays of 1.5% magnesium sulphate solution (plus wetter) were applied 8 times during the season for treatments C and F. The "high potash" treatments D-F received 6oz. of sulphate of potash per sq. yd. as base dressing, and a further 7oz. per sq. yd. in top dressings. The "medium potash" plots received no potassic fertilizers at any time during 1958, soil analysis having shown fair reserves of this nutrient for present purposes. The houses were planted on March 11th.

The soil in these houses had been steamed prior to planting, and the healthy appearance of the subsequent crop contrasted markedly with growth in the same houses during the previous year and also with the unsteamed blocks B and C. Chlorosis of the foliage due to magnesium deficiency developed in mid-season, being most marked where magnesium treatments were not given (A and D). Foliar sprays were again more effective than soil applications of magnesium, though the latter had a considerable effect on the degree of chlorosis.

Soil samples were taken from all plots at the start and end of the season; leaf samples, consisting of the 5th and 15th leaves from the tops, taken separately, were collected in June from all 72 sub-plots. Analysis of the samples has not yet been completed, and discussion of nutrient levels and uptake must accordingly be deferred.

The mean crop yields (lb. per plant) of ripened fruit were as follows:

| <i>Variety</i> | <i>Treatment</i> |          |          |          |          |          |
|----------------|------------------|----------|----------|----------|----------|----------|
|                | <i>A</i>         | <i>B</i> | <i>C</i> | <i>D</i> | <i>E</i> | <i>F</i> |
| 'Potentate'    | 10.4             | 10.3     | 10.1     | 10.4     | 10.5     | 10.0     |
| 'Immuna'       | 11.7             | 12.0     | 11.5     | 11.5     | 11.7     | 11.7     |

The total crop yields are regarded as satisfactory, but show no marked response to the treatments. 'Immuna' again gave higher yields than 'Potentate' throughout.

Fruit from all 72 sub-plots was graded separately throughout the season until October 8th. The results show an increase in the proportions of high grade fruit and a decrease in irregularly coloured fruit of both varieties at the higher level of potash (treatments D-F). The mean percentages of ripened fruit classified as uniformly coloured and of reasonably regular shape (grades A and B combined) were as follows:



| Variety     | Treatment |    |    |    |    |    |
|-------------|-----------|----|----|----|----|----|
|             | A         | B  | C  | D  | E  | F  |
| 'Potentate' | 59        | 61 | 63 | 70 | 72 | 70 |
| 'Immuna'    | 61        | 67 | 65 | 75 | 74 | 75 |

The effects of treatments supplying magnesium on fruit quality as assessed by visual grading were relatively slight, and the data have been submitted for statistical examination elsewhere. The most marked effect of magnesium was found for the variety 'Immuna' at the lower level of potash, the proportion of fruit showing severe irregularity of colour (grade C2) being reduced from 8.5% in treatment A to 4.9 and 4.5% in treatments B and C respectively.

The main conclusions from this experiment to date may be summarized as follows. Despite marked chlorosis of the middle leaves of the plants, particularly in the variety 'Immuna' in mid-season, it has not as yet been possible to demonstrate any significant loss in yield arising from failure to correct the deficiency symptoms, although the latter can be eliminated most effectively. With regard to visual grading of the crop, a marked response to potash fertilizers became apparent in the second season of the trial, and also some response to magnesium treatments at the lower level of potash, but the statistical significance of the latter awaits further examination. Some effects of the nutritional treatments on fruit composition were recorded in an earlier section of this report.

### *3 × 2<sup>4</sup> factorial nutritional trial with carnations (House E2)*

Experiments on the nutrition of glasshouse carnations were commenced during 1958. Visual symptoms of nutrient deficiencies in the crop had previously been studied in sand culture at the Experimental and Research Station at Cheshunt, and growth in sub-irrigated beds of aggregate had also been examined there, but the nutrition of flower crops in soil has of necessity been neglected in recent years. Published work on this subject is still relatively limited, and hence the present phase of the trials in house E2 is of a preliminary nature.

The glasshouse allocated for these investigations was divided off from adjoining houses by glass partitions, and four concrete beds with solid bottoms were constructed, these running the length of the house (north to south). Each bed is 4ft. wide internally, and sub-divided at 8ft. intervals to give 12 experimental plots; small additional sections of bed serve as guard plots at the north and south ends. The bottoms of the beds were shaped to facilitate drainage into the paths; the latter slope to the north end of the house. The beds were filled with a mixture of steamed top-spit loam, peat (20% by volume) and grit (10%).

The factors included in the present phase of the trials were nitrogen at three levels of application, potassium at two levels, and the presence and absence of added phosphorus, magnesium and lime; this gives a total of 48 experimental plots, fully randomized but without replication (there is, of course, much indirect replication). Phosphate, magnesium sulphate and lime (carbonate) were mixed with the composts before filling the beds, the lower level of each of these factors (P1, Mg1, Ca1) representing complete omission of the respective materials. It should be noted, however, that Ca1 denotes the absence of lime but not necessarily of added calcium, since the latter nutrient was present in the form of phosphate used (superphosphate, 18% P<sub>2</sub>O<sub>5</sub>). The levels of application of superphosphate, magnesium sulphate and ground chalk for treatments P2, Mg2 and Ca2 were 9, 3 and 15lb. per cu. yd. respectively. Decisions on the need for any subsequent top dressing with lime or magnesium sulphate in the appropriate treatments will be taken as necessary.

Treatments with nitrogen and potash are applied in solution via a trickle irrigation system of plastic rods sited across the beds, these being fed by a series of 12 sub-mains running down the house. The six diluters are sited over the heating ducts at the south end of the house, each diluter having its own water-meter and pressure gauge. The concentrations of nutrients selected for trial, supplied in the form of potassium sulphate and ammonium nitrate, are as follows:

| <i>Nitrogen (N)</i> |            | <i>Potash (K<sub>2</sub>O)</i> |            |
|---------------------|------------|--------------------------------|------------|
| <i>N1</i>           | 25 p.p.m.  | <i>K1</i>                      | 50 p.p.m.  |
| <i>N2</i>           | 125 p.p.m. | <i>K2</i>                      | 175 p.p.m. |
| <i>N3</i>           | 225 p.p.m. |                                |            |

The actual concentrations of nutrients in the diluted feeds are checked by periodic analysis. It was originally intended that all water applied to the plots would contain these nutrients at the stated concentrations. Unforeseen factors have, however, necessitated some departure from this principle, mainly owing to the accumulation of certain salts at those points in the beds furthest from the trickle outlets. Metered amounts of plain water are therefore being applied on occasions by hose in order to increase the uniformity of distribution of nutrients for experimental purposes.

Previous experience in sand culture had shown varietal differences in the nutrition of the carnation, and the inclusion of more than one variety thus seemed highly desirable. Owing to problems of recording, however, and to uncertainties concerning the minimum suitable size of plot, only two varieties were included in the present experimental plots, these being 'Improved William Sim' and 'Saugus White'. For purposes of recording there are thus 96 sub-plots. The variety used in the guard rows is 'Crowley's Pink Sim'. The stock plants from which the cuttings were taken had been tested for the absence of wilt diseases.

Owing to delays in the multiplication of stocks of planting material the house was not planted up until 24th/25th July. The spacing of the plants is 8 × 8 in., each plot containing 30 plants of 'William Sim', 30 of 'Saugus White', and 12 of 'Pink Sim' in two single guard rows adjoining the cross-partitions between plots. The first blooms were cut in the guard rows ('Crowley's Pink Sim'), and the recording of flower production from the two main varieties commenced at the end of November.

It is as yet too early to discuss the effects of the treatments in terms of either crop records or soil analyses, but several other matters of interest may be mentioned. Thus the lateral spread of water from the trickle irrigation system was clearly retarded at first where phosphate had been applied, possibly owing to aggregation due to the presence of calcium sulphate in the superphosphate. Growth of moss on the surface of the beds was more rapid where phosphate was added.

During October the tips of the lower leaves of variety 'Saugus White' dried up and assumed a pale brown colour in all 24 plots receiving the high level of phosphate; the effect was confined to the one variety, and showed no tendency to spread to any new growth made after planting out in the beds. It seemed highly improbable that this was a direct effect of phosphorus nutrition, and alternative causes such as manganese toxicity are being examined.

The trial will be continued in the present form at least until the spring of 1960, and in addition to the effects of the various nutritional treatments it should provide considerable information on the design of subsequent experiments in this series.

### **Mushroom research (P. B. Flegg)**

The effects of additions of soluble salts, and hence of increased moisture stress, on the fruiting, growth and yields of mushrooms have been further investigated. As a result it is now possible to put forward a new explanation of the functions of the casing layer in mushroom growth, and thus to remove some, at least, of the mystery surrounding this layer.

Fruiting is completely inhibited at high levels of moisture stress, but as the latter is lowered fruiting occurs earlier and the numbers of sporophores formed are increased. The presence of a casing layer is not essential, but the levels of moisture stress in the compost are normally too high to favour fruiting. When, however, the moisture stress at the upper surface of the compost is reduced by suitable means, then fruiting occurs fairly readily. Thus a yield equivalent to nearly 11lb. per sq. ft. was obtained from uncased compost, compared with 1.65lb. from cased compost, by frequent watering to reduce the quantity of salts in the surface layer of the compost. The required conditions for fruiting are, however, more readily attained in the presence of a casing layer. It is concluded that a major function of the casing layer is to provide a medium in which a state of low moisture stress can readily be achieved and maintained over a sufficiently long period.

Measurements of the growth rate of sporophores at increased levels of moisture stress in the casing layer show little effect until quite high levels are reached. It thus seems likely that the primary effect of moisture stress is upon sporophore initiation rather than on their subsequent rates of development. It is not, of course, suggested that salt concentrations and the associated moisture stress constitute the only factor involved in sporophore initiation and development; other important factors doubtless include the nutrient status of the compost and the influence of growth substances.

The addition of soluble salts to the compost reduces the general level of productivity, and the growth rate of the sporophores is also decreased. This is hardly surprising, as the greater proportion of the mycelium is present in the compost, from which it derives most, if not all, of its nutrients. This effect of increased salinity in the compost may be of considerable practical importance, and merits careful examination in any further studies of the materials and methods of composting. Attempts to improve cropping by washing the compost in order to reduce salinity were unsuccessful, though this result may almost certainly be attributed to adverse effects on its nutrient and physical status.

The possible effect on cropping under commercial conditions of the natural accumulation of salts in the casing layer is under investigation.

Attention has also been given to the design and testing of a prototype chamber for studies with mushrooms under controlled conditions of temperature, humidity and aeration. It is planned to construct eight such chambers for use in studies on the effects of environmental conditions on the initiation and development of the sporophore; these chambers should be in operation by the end of 1959.

### **Potting composts (P. J. Sutton and G. W. Winsor)**

Studies on composts for germination and potting, with particular reference to ingredients other than loam, have been initiated in the Department, the work being made possible by a Ministry of Agriculture Post-graduate Scholarship awarded to Mr. P. J. Sutton.



The literature relating to the development of standardised potting media has been surveyed, and a review is presented elsewhere in this Report.

The programme of research includes comparative trials with sand:peat mixtures in varying proportions, as well as the effects of additions of clay. Experiments on the germination and subsequent growth of tomatoes and antirrhinums are in progress, and will be described in a later report.

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### 3. CROP PROTECTION

by

W. H. READ

The Department has continued the investigation of fungicides for the control of *Didymella* Stem Rot of tomatoes and powdery mildew of cucumbers (*Erysiphe cichoracearum*). In this work both compounds synthesised in the laboratory and products obtained from manufacturers have been examined.

Investigations on the control of *Itersonilia perplexans*, which caused serious damage to chrysanthemums during the year, have been commenced. Preliminary work suggests that zineb may be of value in controlling this disease, but methods of ensuring suitable conditions for infection have to be provided before the critical examination of fungicides is possible.

The Department has collaborated with the Entomology Department in work concerned with the control of mushroom flies; this necessitated investigations on the determination of insecticides in mushroom composts.

The problem of controlling Red Spider Mite (*Tetranychus urticae*), particularly on cucumbers, has received further attention. Difficulties are still being encountered because of the high incidence of mildew (*Erysiphe cichoracearum*) on test plants and the effect of fungicidal sprays on the mites.

#### Chemical investigations (J. T. Hughes)

##### *The persistence of insecticides in mushroom composts*

Determinations of the persistence of DDT, BHC, and diazinon in mushroom compost were undertaken in order to assist the Entomology Department in their investigations on the control of mushroom flies. Dusts containing DDT, *gamma*-BHC and diazinon were prepared and incorporated in the compost when the shelves were filled, and the amounts present in the compost determined at intervals over a period of 19 weeks.

Micro methods of analysis were employed as it was anticipated that the amounts of insecticide might become considerably reduced in the course of the experiment, but only small aliquots of extractive were required in the determinations of DDT and BHC. There were no difficulties due to other extracted substances interfering with the determination of DDT or diazinon, but a number of sources of possible error were discovered in the determination of BHC by the Schechter Hornstein method. This method was investigated in some detail and modified for use in large scale routine determinations. The results showed that there is no substantial loss of DDT and that the loss of BHC was insufficient to proscribe its use in this manner. The disappearance of diazinon from the compost was virtually complete between five and twelve weeks of being added to the compost.

##### *The application of gamma-BHC as surface layers to mushroom beds before or after casing, its penetration into the compost and its effect on cropping*

The possibility that adequate control of the larvae of certain mushroom flies can be obtained by applying *gamma*-BHC to the surface of the compost after peak-heating and before casing, or to the casing layer immediately after casing, was suggested by the experience of some commercial growers. Investigations were therefore made to determine the persistence of layers of *gamma*-BHC resulting from the application of this insecticide as a dust or spray immediately before or after casing, and to find whether BHC applied in this manner became distributed in the compost by downward penetration.

A randomised block layout was used, with three replications. The BHC dust was a commercial product containing 1 % *gamma*-BHC and was applied at the rate of 3.3 ounces per square yard as uniformly as possible by means of a small sieve. The BHC spray was prepared by adding an experimental formulation consisting of 0.9g. *gamma*-BHC in 5ml. acetone and 5ml. redistilled petroleum ether, together with 0.9g. cyclohexylamine dodecyl sulphate as a dispersing agent, to 500ml. of water. This suspension, containing 0.18 % *gamma*-BHC, was uniformly sprayed on the compost or casing material at the rate of 1.3 gallons per 100 sq. ft. A similar formulation with the BHC omitted was sprayed on three "cased" plots to serve as controls.

Three cores were cut at intervals from each bed in accordance with a pre-arranged pattern by means of a cylindrical cutter; these were carefully cut into transverse sections corresponding to the casing layer and the upper, middle and lower layers of the compost. The individual sections for each treatment were combined and sub-sampled for analysis by the Schechter-Hornstein method (2) using the simplified de-chlorination procedure of Hancock and Laws (1). The results showed that under normal conditions of mushroom cultivation there was little movement of *gamma*-BHC into the compost.

The average yield for all plots over a cropping period of 9 weeks was 1.8lb. per sq. ft. Statistical analysis of the effect of the treatments on the yield of mushrooms showed that there was no significant difference ( $P=.05$ ) between treatments. There was, however, a significant ( $P=.05$ ) increase in the mean weight of individual mushrooms as a result of the application of the *gamma*-BHC emulsion after casing. This tendency to variation in size of mushroom (which is known to result from other additions to or variations in the casing layer), although not affecting the overall crop weight, may be a commercial disadvantage. Certain mushrooms in the affected plots had abnormally large stalks, and such mushrooms would be of less value than the equivalent weight of mushrooms of more normal proportions. It is possible that lindane influences the growth of the mushrooms in such a way as to cause this distortion, and if so, this would limit the usefulness of surface applications at the level used in this experiment. At lower levels the effect may be unimportant.

## Fungicides (R. J. Smith)

### *Salicylaldehyde derivatives*

A large number of derivatives of halogenated derivatives of salicylaldehyde have been synthesised in the laboratory as potential fungicides in continuance of investigations commenced in 1957. The fungicidal properties of these compounds have been examined in assays against Cucumber Mildew (*Erysiphe cichoracearum*) in glasshouse trials.

Two of the compounds selected as a result of preliminary trials against Cucumber Mildew in 1957, in which they showed considerable merit, have been compared in commercial-scale spray trials against Cucumber Mildew with two established sprays for the control of this disease: "Karathane", a commercial dispersible powder containing 25 % of technical 2:4-dinitro-6-secocetylphenyl crotonate and a copper oxychloride-petroleum mixture.

Two trials were made. In the first, the most readily obtained compound (A) was formulated as a dispersible powder and applied at 0.1 %. "Karathane" was applied at a dilution of 8oz. in 100 gallons, equivalent to 0.013 % active ingredient, and the copper oxychloride-petroleum mixture at 0.05 % copper and 0.3 % petroleum. The available amount of the second compound (B) was restricted, and two half-plots in the same glasshouse were sprayed with it at 0.08 %, this concentration having proved effective in the preliminary trials.



Spraying commenced when mildew was visible on many plants, and further applications were made at approximately fortnightly intervals throughout the period of the trial. Owing to the severity of the mildew attack it was necessary to spray the four control plots from mid-April onwards to prevent their total destruction.

Records were taken of the amount of mildew on the plants in each plot and of the yield of fruit and these are presented in Tables I and II.

TABLE I  
GLASSHOUSE TRIAL ON CONTROL OF CUCUMBER MILDEW; COMPARISON  
OF EXPERIMENTAL COMPOUNDS WITH TWO ESTABLISHED FUNGICIDES

| Treatment                                 | Mean percentage area of leaves infected |            |            |          |          |           |
|-------------------------------------------|-----------------------------------------|------------|------------|----------|----------|-----------|
|                                           | March 24th                              | April 14th | April 30th | May 20th | June 2nd | June 23rd |
| Compound A                                | 2.4                                     | 12.8       | 1.8        | 2.8      | 2.8      | 3.5       |
| "Karathane" WD                            | 6.0                                     | 39.5       | 14.3       | 6.0      | 4.0      | 3.8       |
| Copper oxychloride/<br>petroleum emulsion | 2.9                                     | 28.0       | 3.5        | 2.8      | 1.5      | 2.3       |
| Control (untreated)                       | 52.0                                    | 60.8       | —          | —        | —        | —         |
| Significant difference<br>( $P=0.05$ )    | 11.2                                    | 6.4        | 9.9        | 4.2      | 4.7      | 10.7      |
| Compound B                                | 0.5                                     | 4.5        | 1.5        | 1.5      | 1.0      | 1.3       |

TABLE II  
GLASSHOUSE TRIAL ON CONTROL OF CUCUMBER MILDEW;  
EFFECT OF FUNGICIDAL TREATMENTS ON TOTAL CROP YIELDS

| Treatment                                 | Relative yields<br>("Karathane" = 100) |
|-------------------------------------------|----------------------------------------|
| Compound A                                | 84.0                                   |
| "Karathane" WD                            | 100                                    |
| Copper oxychloride/<br>petroleum emulsion | 92.9                                   |
| Significant difference<br>( $P=0.05$ )    | 16.3                                   |
| Compound B                                | 95.4                                   |

It became apparent in the course of this trial that compound A was too injurious to cucumbers. The addition of an equal amount of calcium carbonate (chalk) was found to reduce its "hardening" effect, and in the second trial comparison was made between compound A, formulated with an equal amount of chalk as a dispersible powder and applied at 0.1 %, compound B at 0.08 %, and "Karathane" at 0.013 %. Each treatment was replicated four times in a randomised block layout. The results, given in Table III, show that compound B gave significantly better control of Cucumber Mildew than "Karathane".

TABLE III

SECOND GLASSHOUSE TRIAL ON CONTROL OF CUCUMBER MILDEW  
(PLANTS SPRAYED ON AUGUST 19th AND SEPTEMBER 3rd)

| Fungicide                                         | Active fungicide (%) | Mean percentage area of leaves infected |            |
|---------------------------------------------------|----------------------|-----------------------------------------|------------|
|                                                   |                      | Sept. 1st                               | Sept. 15th |
| Compound A plus calcium carbonate                 | 0.10                 | 11.3                                    | 12.8       |
| Compound B                                        | 0.08                 | 2.8                                     | 4.3        |
| "Karathane"                                       | 0.013                | 17.0                                    | 19.8       |
| Control                                           | —                    | 41.3                                    | 45.0       |
| Difference required for significance ( $P=0.05$ ) |                      | 4.6                                     | 10.7       |

Compound A, although potentially cheaper than compound B, is too injurious to cucumbers to be acceptable for the control of mildew. Compound B was more promising, but owing to the short duration of the second trial no information on its effect on crop yields is available. Both compounds were more phytotoxic to several other plants, particularly strawberries, than to cucumbers. A full account of the preparation of the derivatives of halogenated salicylaldehydes and of the examination of their fungicidal properties will be submitted for publication when the results of tests with several other derivatives are available.

Thanks are due to Miss H. M. Hughes of Efford Experimental Horticulture Station for conducting a trial with one compound on strawberries, to Mr. P. H. Brown, the Director of the Station, for granting facilities for this trial, and to Dr. A. H. M. Kirby for laboratory assays of three compounds against apple mildew.

#### *Didymella Stem Rot of tomatoes* (W. H. Read)

The withdrawal by manufacturers of ethyl mercury phosphate on account of its high toxicity necessitated the examination of alternative fungicides for the control of *Didymella* Stem Rot of tomatoes. Workers at the National Vegetable Research Station found that maneb (manganese ethylenedis-dithiocarbamate) and captan (N-trichloromethylmercapto-4-cyclohexene-1:2-dicarboximide) showed considerable promise, when applied at high concentrations, in preventing losses arising from an infected soil when the fungicide was applied to the soil immediately around the plant and to the lower six inches of the stem.

As the concentrations suggested are high, repeated applications are expensive; furthermore, the treatment of the base of the stems before the lower leaves have been removed is difficult if undesirable residues on the bottom truss are to be avoided. Trials were therefore made to find out if adequate protection could be obtained from one or two applications of the chosen fungicide and the effect of applying the fungicide to the plants in 3in. pots before planting out in the border was compared with that obtained when plants were treated after planting out. A commercial formulation of captan was chosen for these experiments as the space available for work with *Didymella* was limited, and preliminary tests had shown that at 0.5% it was less injurious to young tomatoes than a maneb formulation at 0.5% active material.

The tomatoes were planted out in a maiden soil inoculated with *Didymella lycopersici* by raking in a sand-oatmeal culture of the fungus after the borders had been cultivated and manured, with composted straw and a normal base fertiliser, in readiness for planting.

In the first trial, in which the treatments were replicated three times in randomised blocks, one third of the plants were treated twenty-four hours before planting out with 0.5% captan whilst still in their 3in. pots; this was done by spraying the lower six inches of their stems and the soil in the pots with a commercial dispersible powder containing 50% captan, each plant receiving three fluid ounces of the preparation diluted at the rate of one pound in ten gallons. A second batch of plants was similarly treated by spraying the stems and the soil surrounding the stems to a radius of about 3in. with 0.5% captan one day after planting. The remaining third of the plants were unsprayed. A second application of five fluid ounces of 0.5% captan was given to previously sprayed plants three weeks after planting.

Plants which became diseased were removed, and their roots examined to confirm that they were infected with *Didymella lycopersici*. Roots of plants still apparently healthy at the end of the trial were also examined. The results of this trial are given in Table IV.

TABLE IV  
CONTROL OF *DIDYMELLA* STEM ROT WITH CAPTAN; MEAN PERCENTAGE  
OF PLANTS INFECTED AT INTERVALS AFTER PLANTING

| Treatment                                                                                      | Weeks after planting |      |      |      |      |      |
|------------------------------------------------------------------------------------------------|----------------------|------|------|------|------|------|
|                                                                                                | 6                    | 9    | 12   | 15   | 18   | 21   |
| 3 fl. oz. of 0.5% captan per plant pre-planting<br>5 fl. oz. of 0.5% captan three weeks later  | 0                    | 3.1  | 8.4  | 16.7 | 18.8 | 22.9 |
| 3 fl. oz. of 0.5% captan per plant post-planting<br>5 fl. oz. of 0.5% captan three weeks later | 8.4                  | 14.5 | 27.1 | 31.3 | 37.5 | 37.5 |
| Control—no applications of captan                                                              | 16.7                 | 41.7 | 66.7 | 93.8 | 97.9 | 97.9 |

Captan applied to the lower part of the stems of tomato plants and to the soil in pots or surrounding the collars of the plants gave a significant reduction in the number of plants infected with *Didymella* in a second trial commenced in July. In this trial, however, the variations between plots were so great that there was no significant difference between single pre-planting and post-planting applications of captan or between either of these and a pre-planting application followed by a second application three weeks later. A feature of this trial was the lower incidence of disease in the untreated control plots (53% of the plants attacked after 20 weeks) and the abnormally long interval between planting and the visible onset of the disease. The presence of the disease in many of the infected plants was not detected until the roots were examined at the end of the trial.

## Insecticides

### *Red Spider Mite control* (W. H. Read)

Investigations on the control of Glasshouse Red Spider Mite have been continued.



Almost complete eradication of red spider throughout the block of cucumber houses at the Institute was obtained by one application of a diazinon aerosol applied at 1.5 grammes per 1,000 cu. ft., but laboratory investigations confirmed that this could not be accounted for by the persistence of diazinon or pronounced ovicidal action. The mortality of adult female mites (red strain) sprayed with diazinon at 125 p.p.m. was 99%, but at 500 p.p.m. there was no significant effect on eggs. Larvae emerging from eggs four days after treatment were unaffected by residual deposits on sprayed leaves.

“Tedion” (2:4:5:4'tetrachlorodiphenyl sulphone) had pronounced ovicidal action. Spraying with this chemical at 500 p.p.m. killed 97.8% of the eggs, but at 125 p.p.m. only 66.9%. Against adult mites it was less effective; the percentage mortalities after ten days were 49.8 at 500 p.p.m. and 31.6 at 125 p.p.m.

Although some female mites sprayed with the tetrachlorodiphenyl sulphone laid infertile eggs, those from other females developed normally to mature, fertile females.

#### *Systemic insecticides* (Valerie A. Gentle)

An examination of the relative values of certain systemic compounds for the control of pests of glasshouse crops has been commenced. Preliminary results have shown that *O.O*-diethyl-*S*-(ethylthiomethyl) phosphorodithioate (“Thimet”) is readily absorbed from soil by cucumbers in acaricidal amounts, whereas *O.O*-dimethyl-*S*-(*N*-methylcarbamoylmethyl) phosphorothiolothionate (“Rogor”) is either less readily absorbed, more rapidly converted to non-acaricidal compounds within the plant, or is less toxic to red spider. “Phosdrin” (2-methoxycarbonyl-1-methylvinyl dimethyl phosphate) was not absorbed from the soil and translocated sufficiently rapidly by young cucumber plants to effectively control active stages of red spider.

#### *Spray damage*

A serious “blindness” and distortion of the growing shoots of certain chrysanthemum varieties, in particular the variety ‘Fred Shoemith’, has been attributed to the effect of a number of insecticidal sprays. Investigations showed that the suppression of apical buds (“blindness”) was an inherent feature of these varieties, or of certain stocks of these varieties, and not due to any insecticide normally applied to chrysanthemums.

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## 4. PLANT BREEDING

by

L. A. DARBY

### Tomato

Breeding programmes have been continued, and selections from crosses of 'Baby Lea' with superior fruited varieties are now at the  $F_5$  generation. In these programmes involving the green-stem compact-habit 'Baby Lea' and other purple-stem tall varieties it has not yet been possible to recombine purple-stem and compact-habit. Whilst this green-stem seedling marker facilitates the very early selection of compact-habit genotypes, many growers judge the condition of young plants by their colour, and the presence of anthocyanin due to the dominant allele is preferable. The genetic control of these two characters is to be examined further.

Replicated trials were conducted at the Institute, though one early crop was discarded because of its excessive vegetative growth. Small observation trials were also grown at certain Experimental Horticulture Stations of the National Agricultural Advisory Service.

A considerable source of inaccuracy in field trials can result from differential infection with pathogens, and this is particularly so in tomato trials involving plots of few plants when exposed to the insidious effects of tobacco mosaic virus infection. In order to try to improve the efficiency of variety trials it was decided to eliminate a possible, though disputed, source of TMV infection, namely via the seed.

All seed for one trial was taken from plants demonstrated to be free from TMV. This was done by means of the local lesion test using *N.glutinosa*, as it is not possible to determine by visual inspection alone, whether or not a plant is free from TMV. Seed of one variety was also distributed to Experimental Horticulture Stations of the National Agricultural Advisory Service for cultural experiments. The use of this seed was coupled with strict hygiene practices in order to reduce the chance of introducing TMV during the life of the crop.

It must be emphasised that no experiments were conducted specifically to determine the value of this seed in reducing early TMV infection, but the general opinion was that some benefit resulted. In view of this experience, it is suggested that the method should be further applied to trials with tomatoes and its value tested experimentally.

### Cucumber

Further generations were produced in the breeding programmes described last year, and two replicated yield and fruit quality trials were conducted.

The first trial was planted initially on 23/12/57 but was discarded because of severe scorch suffered by the plants in attempts to control *Tyroglyphus* mites. This trial was replanted on 25/2/58 and was cropped from 25th March until 27th June. A total of 500 plants representing 20 varieties and hybrids yielded 21,080 fruits weighing 327,193 ounces.

A second trial of similar design was planted on 4th July, and was cropped from 8th August to 2nd September when a large invasion of bees prevented any further accurate work. In this period 5,075 fruits weighing 65,171 ounces were graded and recorded.

### Lettuce

The programme outlined in the last Annual Report was continued.  $R_1$  plants showing sectorial changes in leaf colour were selected and  $R_2$  seed produced.  $F_2$  seed was also obtained from the crosses of 'Cheshunt 5B' with lighter coloured varieties.  $F_1$  plants were as dark green as 'Cheshunt 5B', and intermediate between the parents in hearting.

## 5. STATISTICS

by

D. COOKE

Work in statistics did not begin at the Institute until late in 1958. This report therefore consists of an account of work begun and of plans for future work.

### Design of experiments

Although a large number of experiments have been carried out in glasshouses, very little has been published on the design of glasshouse experiments. Federer (1953) gave a summary of the work up to 1953; useful papers by Alvey (1955) and Lawrence (1955) have appeared more recently. Many of the problems of experimental design in glasshouses await a satisfactory solution, however; the major difficulties arise from the frequently acute limitation of space and from the large yield gradients which often occur in glasshouses.

As a prelude to investigating these problems, existing data from glasshouse tomato experiments are being studied. A major source of data is the results of the uniformity trials which were carried out at the Institute in 1954, 1955 and 1956; these trials have been described, and some of the results quoted, in the Annual Reports for 1954-55 and 1956. The main points of interest in the study of the experimental data are the relation of yield to position in the house, and the magnitude of the residual variability when positional effects are eliminated. The uniformity data are also being used to study the change of variance with plot size and the efficiency of various types of design.

Experiments with mushrooms also offer problems in design. The problems are similar to those which are found with glasshouse crops, though mushrooms offer their own peculiar difficulties. An experiment is being planned in collaboration with Mr. Flegg of the Chemistry Department to investigate some of the problems of experimental technique with mushrooms.

### Timing of harvests in horticultural experiments

Work on this subject was begun while at the Institute of Statistics, North Carolina, U.S.A. A simple mathematical model of the way in which the yield of a crop changes with time was postulated, and the bias in the difference of treatments means, resulting from treatments not being harvested at comparable times, was investigated. This work is being arranged for publication. It is intended to continue the work by considering more closely its application to experiments with particular crops.

### Consulting work

Assistance has been given to other members of the staff in the design and analysis of experiments. One co-operative project deserves particular mention: the investigation of the statistical relation between the percentage of non-uniformly pigmented ripe tomato fruit and various environmental measures. The Plant Physiology Department has collected a large body of data relating to this and has already begun a statistical analysis. There is now active co-operation with the Plant Physiology Department on this project.

The Statistician has taken up work again on the Bulbs and Flowers Working Parties, of the Agricultural Improvement Council's Horticulture Committee, on which he was serving before he went to the U.S.A. in September, 1957. He has also been appointed to serve on the Glasshouse Working Party.

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FEDERER, W. T. (1953). Plot technique in greenhouse experiments. *Proc. Amer. Soc. hort. Sci.*, **62**, 31-34.  
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## PLANT PATHOLOGY DIVISION

This Division was formed in September under Dr. L. Broadbent (appointed 1st August) by combining the Departments of Entomology and Plant Pathology. Dr. Hussey and Mr. Williams remain Heads of the Departments of Entomology and Mycology respectively, and it is hoped to establish ultimately new Departments or sections of Virology and Nematology. For the present virus work remains linked with that on mycology.

While in the U.S.A. at the invitation of the American Phytopathological Society, Dr. Broadbent visited several research stations to study the work being done on tomatoes, flowers and mushrooms, the cost of the extended visit being borne by the A.R.C. At the Jubilee Meeting of the A.P.S. he read a paper on "Insect vector behaviour and the spread of plant viruses in the field". Since returning he has studied the facilities for plant pathological work at research stations in Britain, and produced plans for a new glasshouse block for entomology, nematology and virology. A study of the epidemiology of tobacco mosaic virus in the tomato crop has begun.

Dr. Broadbent will continue to co-ordinate the work on the control of insect-borne potato virus diseases at Rothamsted and elsewhere until the present series of experiments ends. On 2nd December he spoke on "Insecticides and the control of potato virus diseases" at a N.A.A.S. potato conference at Wolverhampton. He accepted an invitation to join the Kirton and Terrington Experimental Husbandry Farms Advisory Committee.

The separate reports on Entomology and Mycology and Virology follow.

## 6. ENTOMOLOGY

by

N. W. HUSSEY

Dr. Hussey gave two lectures on biological approaches to the pest problems associated with mushroom production at area meetings of the Mushroom Growers' Association at East Grinstead and Blackpool. Two young members of the M.G.A. spent about a week in the Department to obtain an insight into research problems and methods associated with mushroom entomology.

The Department exhibited methods of culturing white-flies at the *Conversazione* on "New techniques in pesticide research" organised by the Society of Chemical Industry in March.

**Glasshouse White-fly** (*Trialeurodes vaporariorum* Westw.) (N. W. Hussey, W. J. Parr, and Barbara Gurney)

A large scale pot experiment on the economic effects of white-flies on the cropping of tomato is reported as an appendix to this Report. The aim of this work was to estimate the population which a crop could carry without economic losses, to provide a background for future work on biological control methods. From the data obtained it is concluded that a scale density less than 20 per  $\frac{3}{4}$  in. disc on the apical leaves of the plant would result in minimal loss through sooty mould development.

Subsidiary studies have been made on the effect of plant turgor pressure and leaf ageing on white-fly fecundity. They were designed to provide background knowledge to assist interpretation of the population ecology of white-fly for future observations on the biological control efficiency of different biotic factors. Low turgor pressure decreased the number of eggs laid by each female, but if this were accompanied by an increase in nutrient supply the effect was reversed. White-fly fecundity decreases greatly as the leaf grows older, and further work to determine whether such changes can also be demonstrated as a result of plant senescence or seasonal variations in plant metabolism are still in progress.

A single experiment was done to observe the efficiency of *Encarsia* in the control of white-fly on *Fuchsia*. Different numbers of parasites were liberated simultaneously on caged host plants carrying similar white-fly populations. At different periods after liberation the density of unparasitized scales was determined. Compared with the control populations, reductions of the order of 90% were achieved by the parasites, but the use of plastic cages encouraged sooty moulds as well as the parasitic fungus *Cephalosporium* so that many adult insects perished prematurely. Future critical work will therefore necessitate special facilities. Observations made on the longevity of *Encarsia* suggested that adults lived longer if afforded access to honeydew.

The behaviour of adult female parasites when given a choice between scales within gelatin capsules showed that they are unable to distinguish between unparasitized and parasitized hosts by external stimuli. They searched for eggs of their own kind by probing with their ovipositor within the host scale regardless of the fact that the scale had been probed by the same or another female a few moments earlier.

**Glasshouse Red Spider Mite** (*Tetranychus urticae* Koch) (N. W. Hussey and W. J. Parr)

Data on the rate of development of all stadia at 50°F. were obtained to complete earlier work on the effect of temperature on development.

A few further observations were made on the effect of humidity on fecundity, and it was found that if the condensation droplets on the leaflets under saturation were not too close together females could produce eggs as rapidly as in lower humidities. This suggests that the form of the water film is important, and it is hoped to develop work on the effects of different types of water films on mite reproduction.

### **Mushroom Phorids and Sciarids (N. W. Hussey)**

Considerable difficulties experienced in the rearing of Phorids in laboratory culture have delayed biological studies and necessitated a study of ovariole development. Eggs were not developed unless the females had access to a source of carbohydrate, which is apparently present on the surface of mushrooms. A further difficulty has been due to the use for breeding purposes of flies caught in cropping houses. Dissection of females from the light-trap showed that the proportion containing ripe eggs fell from about 70% in the first two weeks following spawning to as low as 5–10% from the fourth week onwards. This naturally decreases the possibility of choosing a fecund female to initiate cultures, and the discovery last year of the parasitic eelworm *Bradydema*, which renders females infertile, still further reduces the prospect of success with "wild" flies. Some promising results were obtained by imprisoning numerous flies over damp plaster of Paris in plastic pill-boxes, the few eggs laid being removed, surface sterilized and allowed to develop on mushroom cultures on agar.

Data on the longevity of both *Megaselia nigra* and *M. halterata* were obtained, and observations were made on the morphological differences in their developmental stages. This work is to be continued and developed.

Dissections of all stages of *M. halterata* were done to investigate the life-history of *Bradydema*, and it is hoped to publish a paper on the biology of this new species in collaboration with Dr. H. E. Welch of the Parasite Laboratory at Belleville, Ontario.

It may be possible to use repellents against Phorids and other mushroom pests in the two or three weeks following spawning to delay oviposition and so depress population increase relative to the quantity of available mycelium. To obtain preliminary information a range of repellents was tested on a specially designed olfactometer and observations made on their contact repellency. Dimethyl phthalate was the most promising compound.

The light trap was operated in the entomology mushroom house throughout the year to obtain data on population dynamics during the normal cycle of cultural operations. Additional new species of Sciaridae have been trapped which will be described in future taxonomic studies.

### **Mushroom Cecids (N. W. Hussey, I. J. Wyatt, W. J. Parr and Barbara Gurney)**

Mr. Wyatt continued his taxonomic studies and described (in the press) a new species, *Henria psalliotae*, a paedogenetic Cecid from Cornwall.

An experiment on the effect of different nutrient levels on the reproduction of *Heteropeza* showed that as the cultures became older, or were grown on weaker media, the size of the mother and the number of her offspring decreased whereas the time required to complete a generation increased. Those cultures which took a considerable time to develop had a number of "resting-mothers" — a phase in which the maternal cuticle becomes tough and yellow-brown and the one or two daughter larvae may remain within it for several weeks. The experiment suggested that rearing techniques for studies on comparative biology must include frequent transferences to young cultures of the same age. This method was adopted in life-history studies on the four species *Heteropeza pygmaea*, *Mycophila speyeri*, *M. barnesi* and *H. psalliotae*.



Preliminary experiments have been made to develop techniques for studying the effects of humidity on Cecid larvae and also to maintain compost cultures under different and comparatively constant conditions of moisture tension.

In the cropping house the Department was allocated one shelf in a crop grown between January and May. In collaboration with the Crop Protection Department an experiment was laid out to determine the effect of peak heating on a range of insecticides incorporated in the compost before filling. The beds were inoculated with known numbers of Cecid larvae three weeks after spawning, and compost samples were examined regularly thereafter to study population growth. BHC and diazinon survived peak-heat without reduction of the quantity of active chemical and these materials, as well as aldrin, gave control at 100 p.p.m. (parts active ingredient to one million parts compost). All the insecticides used reduced cropping, but BHC and diazinon least (about 20%).

This experience was extended when a whole cropping house became available from August onwards. In an experiment in which BHC was added to the compost as before at rates between 1 and 100 p.p.m., a concentration of 50 p.p.m. restricted the build-up of Cecid populations by one-half without significantly affecting yield.

A second trial was intended to illustrate the economic effects of infecting beds with Cecids at different stages of spawn development. A range of Cecid populations was achieved, but there was no appreciable crop reduction even at the highest pest density. The larval populations finally reached were enormous; considerable mass emigration of larvae took place and adult Cecids swarmed for several weeks. The inference, therefore, is that a healthy mycelium can support a vast Cecid population with little effect on yield, although losses do occur in the later stages of cropping when numerous larvae wander over the stipes and caps of the mushrooms, causing unmarketability and bacterial spread. However, less virile spawn runs would probably succumb to high Cecid populations in the early stages of growth so that incorporation of insecticide as an insurance remains a practical possibility.

A third experiment concerned the use of six more insecticides put in the compost before peak-heating in the search for a more suitable material with the minimum effects on cropping. The effects on yield were small, but no control of Cecids was achieved except by BHC and dieldrin.

Pilot experiments on the effect of BHC on the growth of mushroom mycelium on agar plates demonstrated that the maximum concentration tolerated was 0.001 % *gamma*-BHC. Tests on the effects of such relatively low levels on the physiology of larval reproduction are in progress. This work has become necessary because, despite the control of population increase achieved in the cropping houses, *in vitro* studies showed that concentrations even as high as 1 % required two days to kill the larvae.

#### **Soil fauna (N. W. Hussey, W. J. Parr and Barbara Gurney)**

To utilise an extended research programme initiated by the Crop Protection Department on soil sterilization, a Salt-Hollick apparatus was borrowed from Rothamsted through the courtesy of Dr. Mellanby. Samples of the soil fauna have been taken throughout the areas which are to be sterilized by different methods. This sampling is to be repeated before planting and annually for the next four years.

## 7. MYCOLOGY AND VIROLOGY

by

P. H. WILLIAMS

The work of the Department has been mainly concerned with the effect of cultural conditions on *Didymella* Stem Rot of tomato, the host range of Cucumber Mildew, wilt diseases of the carnation, and mushroom diseases of the "Watery Stipe" type. Further observations have been made on Petal Blight of chrysanthemums, and experiments have been done on the chemical control of Tomato Mosaic. Work has been started on the production of virus-free carnations and on a study of yellow moulds in mushroom compost.

### **Didymella Stem Rot of the tomato (P. H. Williams)**

#### *The effect of plant nutrition on infection*

Tomato plants, variety 'Potentate', were grown in 9in. pots in John Innes potting compost no. 3, in which the proportions of hoof and horn, superphosphate and sulphate of potash were varied as required. Top dressings of mixtures of sulphate of ammonia, superphosphate and sulphate of potash corresponding to those in the experimental composts were given each week. The treatments were arranged in randomised blocks. Three weeks after potting the plants were inoculated by placing equal quantities of J.I.P.3, mixed with 10% by weight of a sand-oatmeal culture of *Didymella lycopersici*, around the base of each stem. The effect of the treatments was estimated by comparing the mean times between inoculation and appearance of lesions, which were:

|                      |                      |           |                                             |
|----------------------|----------------------|-----------|---------------------------------------------|
| <i>Experiment 1.</i> | Standard             | 21.1 days | } Differences not<br>significant            |
|                      | Nitrogen $\times$ 2  | 20.1 "    |                                             |
|                      | Phosphate $\times$ 2 | 21.1 "    |                                             |
|                      | Potash $\times$ 2    | 22.1 "    |                                             |
| <i>Experiment 2.</i> | Standard             | 25.9 days | } Differences<br>significant<br>at 2% level |
|                      | Nitrogen $\times$ 2  | 24.3 "    |                                             |
|                      | Nitrogen $\times$ 4  | 22.3 "    |                                             |
|                      | Potash $\times$ 2    | 28.1 "    |                                             |
|                      | Potash $\times$ 4    | 26.6 "    |                                             |

The softer plants produced by high levels of nitrogen were infected more readily, but in practice it is unlikely that any effect of nutrition occurs as the levels employed in this experiment were much higher than would be used in normal growing.

#### *The effect of temperature on infection*

Tomato plants in J.I.P.3 and inoculated as before were grown in glasshouse chambers (twelve in each) in which the minimum temperatures were kept at 52°, 62° and 72°F. respectively. The chambers were ventilated when the temperature rose 10°F. above the minimum.

In one experiment during April, the mean number of days from inoculation to the appearance of lesions was 20.5 at 52°F. and 28.3 at 62°F., the difference being significant at the 0.1% level. No plant was infected at 72°F. In a second experiment during July, the mean periods were 25.3 days at 52°F. and 27.1 at 62°F., the difference not being significant.

Although the disease developed slightly more rapidly at low temperatures, the final number of diseased plants was the same at temperatures employed in glasshouse practice.

### *The effect of fungal growth in soil on colonisation by D.lycopersici*

Five fungi, which differed in the degree of their antagonism to *D.lycopersici* *n vitro*, were cultured in soil in flasks. After incubation for different periods, the capacity of these soils to inhibit spore germination was tested by the method employed by Jackson (1958). The percentage germination was not significantly affected by diffusates from the inoculated soils when compared with that from sterile soil. The germ tubes were, however, shorter.

Shortening of the germ tubes might be due to depletion of nutrients by the fungi and their action might be simulated by leaching the soil with water. When this was done, both germination and tube growth were considerably decreased. It is possible that not only nutrients, but some substance which stimulates germination in sterile soil were removed by leaching.

This work is being continued.

### **Cucumber Mildew** (Olwen M. Stone)

Work on alternate hosts of cucumber mildew has been concerned mainly with *Sonchus* spp. which have often been found naturally infected. On *S. oleraceus* only small red spots were produced, but typical mildew developed on about 50% of *S. arvensis* and about 90% of *S. asper*. The fungus was transferable back to cucumber after three successive transfers to susceptible *Sonchus* spp.

The percentage of *Sonchus* plants infected varied with the season from none in June to 90% in October, although temperatures in the glasshouse were similar. Inoculations of *Chrysanthemum carinatum* and *C.segetum* also failed in June, but both species became naturally infected in September, the mildew on *C. carinatum*, but not that on *C. segetum*, being successfully transferred to cucumber, *S. asper* and *S. arvensis*. The reasons for the variation in infection are not clear. Age of plant is probably unimportant because *Sonchus* seedlings could not be infected in June but were susceptible in September. Time and intensity of illumination may influence susceptibility and are being investigated.

Few *Ranunculus repens* were infected and no successful transfers were made from the inoculated plants, so this species is unlikely to play an important part in the overwintering of the fungus.

Infection of turnips with mildew can be prevented by supplying the plants with small quantities of zinc (Tomlinson and Webb, 1958). Trials with cucumbers showed that the addition of 0.5 or 1 p.p.m. of zinc sulphate to the culture solution damaged the plants but did not prevent infection. With 10 p.p.m. of boron as boric acid in the solution, 7 of 12 became infected, and with 25 p.p.m., 3 of 12, but the plants were severely damaged.

### **Chrysanthemum Petal Blight** (*Intersonilia perplexans*) (Olwen M. Stone)

*Intersonilia perplexans* Derx caused much damage to chrysanthemums during 1958, especially to the flowers of plants grown out of doors or in cold houses.

At the Royal Horticultural Society's Gardens at Wisley each of 144 varieties was affected and there appeared to be no varietal resistance. The fungus was also isolated from chrysanthemum leaves. It attacked some varieties of dahlias, especially pompoms, and was isolated from leaves, but only when they were infected as well by smut (*Entyloma dahliae* Syd.). It was isolated from petals of *Pyrethrum*, *Zinnia*, *Tagetes*, *Cosmos*, *Gaillardia* and *Gerbera*. An isolate of the fungus from parsnip canker obtained from the National Vegetable Research Station did not infect chrysanthemum nor did the chrysanthemum fungus affect parsnips.

Work on the effect of atmospheric humidity and of other factors on this disease is in progress.



## Carnation Wilt Diseases (Marion H. Ebben)

### The "cultured cutting" test

#### (a) Sterilisation of cuttings

Surface sterilisation of the base of the cutting is the first step in the test. A vital stain, methylene blue, penetrated 1-1½ in. in 5 minutes, 1½-2 in. in 10 minutes and 1½-2¼ in. in 15 minutes. If sterilising agents are taken up to the same extent, treatment for only five minutes might kill pathogens in the portion of stem used for the test, which may then give a false result as the pathogen may be present higher up the stem in the portion struck.

To test the efficiency of different methods of surface sterilisation, *Fusarium roseum*, *F. oxysporum* f.sp. *dianthi*, *Verticillium cinerescens*, *Pectobacterium carotovorum* f.sp. *dianthi* (carnation pathogens), *Chaetomium* sp. and a Gram-positive bacterium (both common saprophytes) were cultured for eight days in broth. Pieces of washed sterilised matchstick were then soaked in the cultures for about five hours and plated on potato dextrose agar after surface sterilisation by the following methods:—

1. Calcium hypochlorite 7% for 5, 10 and 15 minutes.
2. 70% alcohol — material dipped and flamed.
3. Mercuric chloride 0.1% — material washed first in 70% alcohol, treated 30 seconds and 1 minute, rinsed in 8 hydroxyquinoline sulphate 0.1% and flamed.
4. Mercuric chloride 0.1% — material washed first in 70% alcohol, treated 30 seconds and 1 minute, rinsed in water.
5. 8 hydroxyquinoline sulphate 0.1% in 70% alcohol, 1 minute and 2 minutes, flamed off.
6. Silver nitrate 1%, 30 seconds, 1 minute and 2 minutes, passed through 15% sodium chloride solution, rinsed three times in water.
7. Sodium hypochlorite 1 in 10 dilution of 10-14% solution for 5, 10 and 15 minutes.
8. Controls (a) no treatment, (b) washed in sterile water 5 minutes and (c) flamed.

All the methods except 70% alcohol and silver nitrate were effective against all the test organisms. Alcohol did not eliminate either of the bacteria. Silver nitrate was ineffective against *F. oxysporum* f.sp. *dianthi*, *Chaetomium* sp. and both bacteria. Growth was obtained from all the control matchsticks.

Further surface sterilisation tests against natural surface contaminants were carried out using cuttings. The treatments were:

1. The method recommended by Hellmers, i.e., 3 above, with treatment in mercuric chloride for 30 seconds.
2. Mercuric chloride 0.1% 15 minutes, rinsed in sterile water, dried and flamed.
3. Potassium permanganate 4%, 15 minutes, rinsed in sterile water, dried and flamed.
4. Calcium hypochlorite 7%, 15 minutes, rinsed in sterile water, dried and flamed.

The percentage contaminations were:— (1) 54, (2) 32, (3) 68 and (4) 32.

Potassium permanganate is reported to be more effective than other disinfectants against the Gram-positive spore forming bacteria which form the majority of contaminants in such tests, but it was not effective in this trial. The best results were from the 15 minute treatments with mercuric chloride and calcium hypochlorite. Calcium hypochlorite was effective against fungi but less so against bacteria. Mercuric chloride for 15 minutes was most effective against bacteria

but fungal contamination was high. Fungal growth was least where mercuric chloride was washed off with 8 hydroxyquinoline sulphate. It might be possible to combine these two treatments if penetration of mercuric chloride up the xylem is not too extensive. Alternatively a higher concentration might be used for a shorter time.

*(b) The effect of different factors on bacterial contamination*

Cuttings from different sources were tested for wilt diseases before being rooted for eventual planting in houses E2 and E3. They were surface sterilised with mercuric chloride as in Hellmers' method above. The percentage of tubes with bacterial growth was high, and streaking on agar showed that most of the bacteria were non-pathogenic. This led to tests to find out if contamination could be decreased.

- (i) Sections cut from nodes might be more difficult to sterilise than internodes, because of the remains of leaf bases, but this proved not to be so.
- (ii) Standing freshly plucked cuttings in 70 % alcohol for 3 minutes before transferring to the laboratory did not decrease the proportion of contaminated cuttings.
- (iii) Part of a batch of cuttings was stored in plastic bags in a refrigerator until they could be tested. Contamination was 30 % in those tested immediately but 61 % and 90 % respectively in those tested after 4 and 5 days. The moist conditions in the plastic bags apparently favoured the increase of contamination.
- (iv) No consistent connection between the personnel performing tests and contamination of cuttings was found.
- (v) The proportion of infected or contaminated cuttings was not consistently affected by the age of the nutrient broth, nor by the length of time it had been autoclaved.
- (vi) Crystal violet is reported to have a bacteriostatic action on Gram-positive bacteria, which include many saprophytes. Three isolates of the slow wilt bacterium grew in Difco glucose broth containing 0.01 % crystal violet, but the three wilt fungi and two saprophytic bacteria did not. In tests using pieces of stem from diseased plants, all three wilt fungi and the slow wilt bacterium grew out satisfactorily and could be isolated in pure culture.

Stem sections from 400 cuttings were placed in Difco glucose broth and in Difco glucose crystal violet broth. In the broth without crystal violet 55 % were contaminated, 54 % with bacteria and 1 % with fungi. In the crystal violet broth 2.2 % were contaminated, 1.2 % with bacteria and 1 % with fungi. In a second trial 20 cuttings of each of three varieties were cultured and the tubes examined after 5 and 11 days. There was no growth in 5 days in the crystal violet broth, in contrast to 32 % contamination in the Difco glucose broth. After 11 days, 28 % of the crystal violet tubes showed growth, and 55 % of the Difco glucose, but the type of growth differed. In the crystal violet broth 10 % showed bacterial and 18 % fungal growth, the corresponding figures in Difco glucose being 52 % and 3 %.

The results of these experiments may be summarised as follows:

(1) Bacterial contamination may show as either a diffuse or surface growth in broth tubes. Fungal contamination when originating from the cutting shows as hyphae growing out from the stem section.

(2) *Chaetomium* spp. are frequently isolated and many of the bacteria are Gram-positive spore-forming contaminants.

(3) The incidence of contamination depends on:

- (a) Source of cuttings; in any one variety contamination may differ from time to time from the same plot, or from plot to plot at the same time.
- (b) Method of surface sterilisation. Time of treatment is important. A greater concentration of the sterilising agent with a shorter time might give better results, and this will be tested.
- (c) Time and condition of storage of cuttings, because moisture on cuttings favours the spread of contaminants.
- (d) Type of broth; the addition of crystal violet to broth largely decreased bacterial contamination.

#### *Observations on disease incidence in a glasshouse*

The plants in house E1 were removed in September, 1958, when they were  $3\frac{1}{2}$  years old. The number dying increased from 15% in  $2\frac{1}{2}$  years to 50% in  $3\frac{1}{2}$  years. The worst affected variety was 'William Sim' with 61% loss, and the least affected was 'Ashington Pink' with 31%. Losses were mainly due to stem rot caused by *F. roseum*. The infection appeared to have started late, and, judging from the distribution of diseased plants, occurred at random, not spreading from one plant to another.

Many of the remaining plants had slightly discoloured pith and xylem. Isolations were made from a sample of plants from each bed. *Fusarium oxysporum* and *F. roseum* were isolated from a few plants of the variety 'Northland'. The soil fungi *Cephalosporium* sp., *Chaetomium* sp. and *Paecilomyces* sp. had penetrated the base of the stem of others, especially where the pith was rotten. No doubt the general debility of the plants favoured their penetration.

#### *The fungal flora of steamed and unsteamed carnation soils*

Three plots in house E1 were steamed in February 1958, after the removal of the  $3\frac{1}{2}$  year old plants. The fungus flora was examined by means of dilution plates and Warcup's soil plates, 10 days and 4 months later. Sediment from the dilution flasks was also plated by Warcup's method.

In the steamed soil, the numbers of fungi increased from 12,000 per gm. of dry soil to 80,000, the increase being mainly of *Trichoderma* sp. In the same period, numbers in the unsteamed soil fell from 194,000 to 113,000 per gm. dry soil; here *Penicillium* spp. were dominant.

*Fusarium roseum* was isolated from both the steamed and unsteamed soils at the second sampling. Re-infection of the soil may have come from carnation plants in the same house or from a wheat field outside. As disease caused by this fungus is so prevalent, its relative scarcity in the unsteamed soil was surprising.

#### *Growth and survival of carnation fungi in soil and composts*

An experiment was started in 1957 to see if fungi associated with carnation diseases could grow and survive in different soil types. The soils and other mixtures used were: 1:1 peat and sand (pH 4.5), sand oatmeal medium (pH 6-6.3), maiden loam (pH 7.0), John Innes compost (pH 7.2). They were brought to 25% moisture content and sterilised by autoclaving, then inoculated with *Verticillium cinerescens*, *Fusarium oxysporum* f.sp. *dianthi*, two strains of *F. roseum*, *F. solani*, *Alternaria gypsophilae* and *Didymellina dianthi*, all isolated from carnation, and *Paecilomyces variotii*, a soil fungus secondarily associated with stem rot of carnations. The flasks were incubated at room temperature. After 4 and 17 months they were sampled by counting the numbers of colonies that developed on plates inoculated with 0.5g. soil.



As was expected, the leaf inhabiting fungi soon died out. The remainder survived best in John Innes compost and the maiden loam, possibly because these had a higher pH and dried out less rapidly.

#### *A possible bacterial infection of carnation cuttings*

During the summer a number of newly rooted cuttings of 'Saugus White' wilted after potting. Growth was poor and a grey green wilt and some foot rot developed. In badly diseased plants the xylem was discoloured and rotten, with a shreddy texture, and the whole of the lower part of the stem was shrunken. Bacteria isolated from these plants did not resemble either of the known bacterial pathogens of the carnation. Healthy cuttings were inoculated by standing them in a bacterial suspension and rooting each separately in plastic pots. Both inoculated and control cuttings of 'Saugus White' developed a grey green wilt accompanied by shrivelling of the stem base. Cuttings of 'Betty Lou' remained healthy. Re-isolations gave no conclusive evidence that the bacterium was responsible for the disease. The fact that mildly diseased cuttings recovered and that 'Betty Lou' showed no symptoms when inoculated suggests that the bacterium is at best only weakly pathogenic and that poor rooting was the primary cause of the trouble.

#### **Mushroom diseases (Doreen G. Gandy)**

##### *Experiments on disorders of the "Brown Disease", "Watery Stipe" type*

Experiments were done during the year to find out if "Brown Disease" or similar disorders could be transmitted by compost or casing material from affected crops, or by spawn made from mycelium or fruit bodies from such crops. Observations on the growth of cultures isolated from abnormal crops were continued in the laboratory.

##### *(1) Experiments with compost and casing material*

The earlier experiments were done under adverse conditions, before the completion of the new mushroom research unit. The composts used were poor and the spawn grew slowly, producing poor crops even in the control beds and trays. In addition, very large populations of cecid larvae developed in the beds inoculated with compost or casing material from affected crops from commercial farms. Consequently, the failure of the inoculated beds in the first experiment (in house 1), which gave a mean yield of 12% in number and 12% in weight of the controls, and of the inoculated trays in the second experiment (in house 2) which gave a mean yield of 21% in number and 17% in weight of the controls, could not be attributed to infection as a result of inoculation, but might have been caused by cecid attack on weakly growing mycelia. Abnormal mushrooms occurred in all treatments, namely, in the controls and in trays inoculated with material from normal or from affected beds; they included watery streaks, underdeveloped gills and veils, bent stipes, long stipes and premature death, and experiments by the entomologists have shown that these symptoms occur when cecids are numerous. The experiments are being repeated in one of the new houses, and an insecticide has been incorporated in the compost to control cecids; results are not yet available.

Thus no evidence has been obtained yet to suggest that "Brown Disease" is transmissible, nor could its appearance be correlated in any way with external winter conditions at Littlehampton.

##### *(2) Spawns from diseased crops*

Ten spawns prepared from isolations from affected mycelium and sporophores were used in a growth study. Yields differed greatly, numbers varying from 19% to 188% (mean 97%) of the control, and weights from 8% to 145% (mean 65%). The fruit bodies on the inoculated plots were thus smaller than those on the controls.

In a second experiment in the new house, nine isolates were tested on synthetic compost and on horse manure compost. Mycelial growth was very poor and in most instances no mushrooms

were produced. The lack of vigour shown by most of the strains when grown in compost agrees with observations made on their growth on agar media.

### (3) *Laboratory experiments*

Measurements were made of the growth rates of seven isolates from abnormal crops on agar media; they varied from 34% to 87% (mean 47%) of the controls.

Isolations were made from mycelia from the experiment in house 2 in which cecids were numerous. Of 26 isolations, 23 showed the adpressed type of growth frequently noted in isolates from abnormal crops. These grew much more slowly than the normal fluffy types, averaging 32mm. in seven weeks against 75mm. Both types appeared to be stable when grown on different media and the adpressed type did not revert to the fluffy type. This suggests possibly a genetical change and is supported by the fact that colonies of the two types do not fuse when incubated together on an agar plate, whereas two fluffy type colonies grow together and the coarse mycelial strands of each colony anastomose.

### (4) *Experiments with a strain stated to be parasitised by a bacterium*

It has been reported that cultures of mushroom mycelium may be contaminated by a bacterium which causes lysis of the mycelium. When cropped, such cultures produce some mushrooms which are deformed and sticky and which in section show translucent streaks. If confirmed, this might prove to be a cause of the "Brown Disease". Three trays were spawned with a culture stated to be contaminated, and were compared with trays spawned with commercial spawn. The yield was slightly less, and a few brown and sticky mushrooms appeared on the trays spawned with the contaminated culture, but mushrooms with underdeveloped gills and watery streaks appeared on both sets of trays. No disorder developed approaching the severity of those which have occurred on commercial farms. Every effort was made to confirm the presence of bacteria in the culture but without success.

### *Yellow moulds in mushroom compost*

The study of these moulds, which was started at the Mushroom Research Station, Yaxley has been resumed, but so far it has not been possible to induce them to grow on agar media.

## **Virus diseases**

### *Tomato mosaic (R. Howles)*

Phenoxy acids applied to the foliage and roots of tomato plants grown with their foliage in contact did not prevent the spread of tobacco mosaic virus. Watering plants with solutions of 25 and 5 p.p.m. thiouracil decreased spread on one experiment, but this was not confirmed by later work. A brief special report on this and previous work along the same lines is published elsewhere in this Report. Although the results are negative or inconclusive they are presented to save the time of other research workers.

Experiments on freeing tomato seed from virus by treatment with 2-chlorophenoxyacetic acid were inconclusive and are being continued.

### *Production of virus-free carnations (Olwen M. Stone and R. Howles)*

Work has been started on the problems met with in attempting to produce virus-free carnation plants by meristem culture after heat or chemical treatment.

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2. TOMLINSON, J. A. & WFBB, M. J. W. (1958). Control of turnip and cabbage mildew (*Erysiphe polygoni* DC) by zinc. *Nature, Lond.*, **181**, 1352-1353.

### III. SPECIAL RESEARCH REPORTS AND REVIEWS

#### 1. INTERIM REPORT ON THE SECOND STAGE OF THE TOMATO GROWTH ANALYSIS

*by*

**A. J. COOPER**

The first stage of the growth analysis occupied the three years 1954-56 and showed that similar changes in the development of the organs of the tomato occurred at similar times in each year.

To obtain further information about the meaning of "time of year" and the interaction of plant age the second stage of the growth analysis work was begun. The year was divided into nine periods of 40 days and seed of the variety 'Potentate' was sown at the beginning of each period, the first sowing being made on October 27th, 1957 and the last on September 12th, 1958. Within a few days of germination five identical seedlings were selected from each sowing and planted 6 feet apart in the border of a vinery type glasshouse, all axillary shoots being removed as soon as they appeared.

From planting until the growing points of the plant reached the ridge of the glasshouse (16ft.) records are being taken of the development of all the organs except the roots. As a plant takes just over one year to reach the ridge the recording of the data of this second stage of the growth analysis work should be completed in late 1959.

The collecting of such a vast body of data from an adequate number of plants over what will be a period of continuous recording of more than two years is straining labour and computing resources to the limit. It has thus, perforce, been found necessary to abandon any attempt to analyse the data until the pressure of data collection eases, and consequently the publication of a more detailed report must of necessity wait until the analysis of the data can be begun.

#### **Growth analysis: latitude trial**

To obtain additional data relevant to the study of the interaction of plant age and "time of year" on the growth of the tomato under glass the third sowing (January 15th) in the above experiment was replicated at three different latitudes, namely 49°30' N (Guernsey), 52°45' N (Sutton Bonington) and 55°30' N (Auchincruive). The latitude of the Institute is 50°45' N.

This extension of the work was made possible through the collaboration of Messrs. D. G. Le Tissier, J. G. Gillow and R. G. Siddall in Guernsey, Professor J. P. Hudson at Sutton Bonington, and Dr. H. F. Dovaston and Mr. J. Love at Auchincruive.

Owing to the pressure of recording already mentioned it will be some time before the data from these other latitudes can be analysed.

Through the co-operation of Mr. E. R. Keighley of the N.A.A.S., it has been possible to make arrangements for the January 15th sowing to be extended in 1959 to Finland (60°15' N) and Malta (36° N). This, in conjunction with the 1958 data from different latitudes within the British Isles, should give an adequate range of light duration.



## 2. A NOTE ON THE RELATION BETWEEN THE POSITION OF TOMATO INFLORESCENCES AND AXILLARY SHOOT GROWTH

by

A. J. COOPER

It has been shown that the vigour of growth of axillary shoots in the 'Potentate' variety of tomato is related to their position with respect to the inflorescences (Cooper, 1956). The axillary shoot arising in the axil of the leaf immediately below an inflorescence has a more rapid rate of extension growth than the axillary shoot arising in the axil of the leaf immediately above an inflorescence, while the intermediate axillary shoot—there are usually three leaves and three axillary shoots between inflorescences—has an intermediate degree of vigour.

To test whether this pattern of vigour is affected by the presence of the inflorescences the axillary shoots arising between the 5th and 6th inflorescences of twelve plants sown on October 27th were allowed to develop, all other axillary shoots being removed as soon as they appeared. Axillary shoots were also allowed to develop between the 9th and 10th inflorescences of twelve plants sown on the same date, and between the 6th and 7th inflorescences of fifteen plants sown on December 20th.

The plants from each of these three treatments were divided into three groups. In one group the lower of the two selected inflorescences was removed as soon as it was possible to do so without damaging the growing point of the plant, in the second group the upper inflorescence was removed, while in the third group both the inflorescences were allowed to remain. After approximately three weeks' growth the axillary shoots were measured, and the mean lengths of the upper, middle and lower axillary shoots in each group are shown in the Table.

TABLE  
MEAN LENGTHS OF AXILLARY SHOOTS (cm.)

| Inflorescence position | Lower inflorescence removed |                 |                | Upper inflorescence removed |                 |                | Both inflorescences present |                 |                |
|------------------------|-----------------------------|-----------------|----------------|-----------------------------|-----------------|----------------|-----------------------------|-----------------|----------------|
|                        | Upper axillary              | Middle axillary | Lower axillary | Upper axillary              | Middle axillary | Lower axillary | Upper axillary              | Middle axillary | Lower axillary |
| 5th & 6th              | 31                          | 28              | 10             | 24                          | 24              | 11             | 25                          | 25              | 9              |
| 6th & 7th              | 47                          | 35              | 0              | 39                          | 27              | 0              | 48                          | 44              | 0              |
| 9th & 10th             | 45                          | 27              | 0              | 34                          | 24              | 0              | 54                          | 46              | 0              |

It can be seen that the removal of either the upper or the lower inflorescence had little effect on the pattern of vigour of axillary shoot growth and in all cases the most vigorous axillary shoot was that arising in the axil of the leaf immediately below an inflorescence (the "upper axillary"), while the least vigorous was the shoot arising in the axil of the leaf immediately above an inflorescence (the "lower axillary").

The conclusion can thus be drawn that the presence of the inflorescences *after the stage at which they were removed in this trial* had little effect on the growth of the axillary shoots.

### REFERENCE

COOPER, A. J. (1956). Further observations on the growth of the root and the shoot of the tomato plant. *Rep. XIVth Int. hort. Congress, 1955*, 589-595.

### 3. THE EFFECT OF PLANTING DENSITY ON THE YIELD OF THE 'POTENTATE' TOMATO

*by*

A. J. COOPER and J. M. EVANS

It was shown in a previous trial, in which planting densities of 10,890, 14,520 and 21,780 plants per acre were compared, that the closest spacing tested gave the greatest weight of fruit per unit area of glasshouse (Cooper, 1959a). At the 0.05 level of probability the reduction in yield given by the widest spacing was significant, but the increase in yield given by the closest spacing relative to the intermediate density was not significant.

The present trial was carried out to test the hypothesis that there is a planting density above which further increase in density fails to increase yield. A planting density midway between the two higher densities referred to above, namely 17,424 plants per acre, was compared with the greatest planting density feasible on a large scale under glass, namely, 24,891 plants per acre. These two planting densities were replicated three times in a randomised layout in a vinery type glasshouse 29ft. wide and 100ft. long. Each treatment plot occupied the same area of glasshouse space, and was surrounded by guard plants. The rows of plants ran from north to south and the distance apart of the plants in the rows was 1ft. This within-row spacing was based on the work of Sheard (unpublished data) which shows that the closer tomato plants are spaced within the row the greater the yield per unit area of glasshouse where conditions are such that competition between the rows themselves is slight or non-existent. The density of 17,424 plants per acre was achieved by spacing single rows  $2\frac{1}{2}$ ft. apart. The density of 24,891 plants per acre could only be achieved in a practical manner by using a double row planting pattern; double rows 1ft. apart were therefore spaced  $2\frac{1}{2}$ ft. apart. There is, however, little evidence in the literature to suggest the existence of an interaction between planting pattern and planting density in relation to yield (Cooper, 1959b).

Owing to the fixed positions of the 4in. diameter pipes of the heating system some of the plants had to be grown closer to the heating pipes than was desirable. To prevent the desiccation of leaves that touched the heating pipes, it was necessary to insulate some of the pipes in places. As a result, night minimum air temperatures were lower than was desirable during very cold weather.

An attempt was made to ensure that soil moisture and soil nutrients were supplied in excess of requirements so that the effect, if any, of between-row spacing would be one of "aerial" competition and not edaphic competition. Water and fertilisers were applied uniformly over the whole experimental area irrespective of plant spacing. Nitro-chalk and a proprietary potash-phosphate compound fertiliser were each applied at the rate of 1oz. per square yard each week from planting. The amount of water applied varied throughout the season, the criterion being the visual one that the soil, as indicated by auger borings, should be very moist, down to a depth of 3ft., from the date of planting onwards; "ball" watering was not practised.

The seed was sown in John Innes Seed Compost in seed trays on December 27th. The seedlings were pricked off into  $3\frac{1}{2}$ in. pots as soon as they were big enough to handle, and planted out on February 6th, when the first truss was just visible. At this stage the roots had grown out to the edge of the pots, but the plants were far from being "pot-bound". Axillary shoots were removed as soon after they appeared as was possible.

Picking was carried out daily (excluding Sundays). The fruit was weighed in bulk on a treatment plot basis, but the colour grade of each fruit was recorded individually according to the system already outlined (Cooper, 1958).

## Results

The data for yield, fruit number, mean fruit size and the percentage of fruit in the six pigmentation grades are shown in the Table for the two planting densities. The colour grading was extremely strict, and fruit that had the slightest trace of uneven colouring was rejected from the uniformly coloured grade.

TABLE  
YIELD OF FRUIT, MEAN FRUIT WEIGHT, FRUIT NUMBER,  
AND PERCENTAGE UNIFORMLY AND NON-UNIFORMLY COLOURED FRUIT

|                                      | Plants per acre |           |
|--------------------------------------|-----------------|-----------|
|                                      | 17,424          | 24,891    |
| Mean weight of fruit picked per plot | 258,483g.       | 262,168g. |
| Mean number of fruit per plot        | 4,885           | 5,404     |
| Mean fruit weight                    | 52.9g.          | 48.5g.    |
| Uniformly coloured fruit             | 40.9%           | 46.0%     |
| Non-uniformly coloured fruit:        |                 |           |
| Grade A                              | 25.5%           | 23.0%     |
| Grade B                              | 0.4%            | 0.4%      |
| Grade C                              | 3.6%            | 3.9%      |
| Grade D                              | 0.6%            | 0.4%      |
| Grade Z                              | 29.8%           | 26.4%     |

There was no significant effect of planting density on the yield. This was due to the fact that with increased planting density the increase in the number of fruit produced per unit area was offset by a decrease in the mean weight of the fruit. This decrease in mean fruit size was significant at the 0.05 level of probability. The effect on fruit number was not significant, but it approached significance very closely.

When the early yield is considered, i.e., the yield over the first three weeks of picking, similar trends can be seen but they are not significant at the 0.05 level of probability. The size of the fruit picked from the closer planting tended to be smaller than that of the fruit from the wider planting, and this difference approached significance. The number of fruit picked from the closer planting tended to be greater and consequently, as for total yield, this offset the decrease in fruit size and there was no difference in the weight of early fruit picked from the two planting densities.

There was no significant ( $P=0.05$ ) effect of planting density on the production of uniformly coloured fruit, nor were there any significant differences between the amounts of the individual grades of non-uniformly coloured fruit produced at the two spacings. The season was a very cloudy one with little sunshine, and it is of interest to note that there was practically no fruit in Grades B, C and D. The non-uniformly coloured fruit consisted mainly of Grade A and Grade Z fruit.

When considered in conjunction with the 1957 results the data suggest that with an increase in planting density up to a certain number of plants per acre there is an increase in fruit number produced per unit area of glasshouse space, the planting density having little effect on fruit size.



Consequently there is an increase in yield per unit area. Further increase in planting density increases the fruit number produced per unit area but decreases the size of the fruit produced. Consequently there is no further effect on yield. The data suggest that the density above which there is no further marked increase in yield lies between 14,500 and 17,500 plants per acre.

Since these are high planting densities it would appear that, from the practical point of view, the factors limiting the increasing of yield by increasing the planting density are not connected with interplant competition but with factors involved in ease of management and disease incidence. These factors lie in the realm of economics and are beyond the scope of plant physiology.

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#### 4. PRELIMINARY OBSERVATIONS ON SOME EFFECTS OF TEMPERATURE ON THE COLOUR OF TOMATO FRUITS ON THE PLANT

by

A. J. COOPER

In the review of the literature on blotchy ripening published in a previous Annual Report (Cooper, 1958) it was suggested that there was some evidence of a relation between non-uniform ripening and the existence of temperature gradients across the fruit tissue.

As part of the current programme of work on abnormal pigmentation it was decided to investigate the use of equipment capable of localised heating of small areas on a tomato fruit while the fruit was still attached to the plant, and the prototype equipment shown in the Plate was constructed. Each heating unit consisted of a tube open at one end. To the open end of the tube a truncated plastic cone was fixed. The tip of the cone was cut across to provide an aperture corresponding to the area of the fruit surface that it was desired to heat. The tube contained a heating mat controlled by a thermostat. The two heating units were mounted on a supporting framework so that they could be positioned readily on opposite sides of a tomato fruit. The heating units were covered with metal foil and shaded by a polished aluminium shield to reduce radiation effects. Thermometers were inserted in the plastic cones in such a position that the bulbs were very close to the surface of the fruit. These gave a rough estimate only of the fruit tissue temperature, and due to conduction the tissue between the two heated areas was at varying unknown temperatures above ambient air temperature.

The heating units were placed in position when a fruit was approaching the mature green state, i.e., when there would be little further increase in fruit size. The fruit was removed from the plant when any part of it reached a standardised degree of redness. A suitable colour measuring instrument was not available, so this standardisation depended on the ability of the observer to retain a colour impression over a long period.

Temperature gradients were maintained at different times of the season across seven fruit. With all fruits the air at the surface of one of the heated areas was kept at approximately 75°F. as measured by the thermometer near the fruit surface; the air temperatures maintained at the other heated area are shown in the Table. The area that developed its red colour first is shown in *italics*.

It is of interest to note that as the temperature gradient was increased the area to redden first (*italics*) changed from the hotter area to the intermediate area, suggesting that there exists an optimum temperature for reddening that is above the temperature maintained at the cooler side of the fruit and below the temperature maintained at the hotter side, but in the absence of suitable equipment for measuring fruit tissue temperature it was not possible to obtain more than a rough indication of the temperatures concerned.

An attempt has been made in the Table to define the colours of the different areas of the fruits. In the absence of an instrument to record the colour data, and in the absence of any reasonably accurate estimates of the fruit tissue temperatures, it is not advisable to attempt to draw any conclusions other than that localised differences in the colour of tomato fruit occur when temperature gradients are established across fruit.



PROTOTYPE EQUIPMENT FOR  
PRODUCING A TEMPERATURE  
GRADIENT ACROSS A TOMATO  
FRUIT







TABLE

COLOUR DIFFERENCES ASSOCIATED WITH TEMPERATURE GRADIENTS  
ACROSS TOMATO FRUIT

| Fruit no. | Area                                             | Air temperature gradient | Colour                                                      |
|-----------|--------------------------------------------------|--------------------------|-------------------------------------------------------------|
| 1         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-110°F                 | Deep red<br>Medium red<br>Pale red                          |
| 2         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-121°F                 | Deep red<br>Deep red<br>Yellowish-red                       |
| 3         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-127°F                 | The colour of a common wax candle<br>Deep red<br>Medium red |
| 4         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-137°F                 | Greenish-yellow<br>Deep red<br>Medium red                   |
| 5         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-161°F                 | The colour of a common wax candle<br>Deep red<br>Deep red   |
| 6         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-165°F                 | Yellow<br>Deep red<br>Deep red                              |
| 7         | <i>Hot</i><br><i>Intermediate</i><br><i>Cool</i> | 75-173°F                 | Yellow<br>Deep red<br>Deep red                              |

## REFERENCE

COOPER, A. J. (1958). Blotchy ripening and allied disorders of the tomato: a critical review of the literature. *Rep. Glasshouse Crops Res. Inst.* 1956, 39-47.

## 5. A NOTE ON THE MEASUREMENT OF THE FIRMNESS OF TOMATO FRUIT

by

G. E. HOBSON

For studies of the chemical and biochemical changes occurring during the ripening of tomato fruit it is necessary to select graded batches of fruit at various stages of ripeness; furthermore the stages of ripeness selected for study must be as reproducible as possible.

Of the many methods by which to judge the maturity of fruit no single criterion appears to be particularly satisfactory. But by combining methods based on two or more characteristics that change in a regular manner during ripening, the effects of inaccuracies arising from the individual methods can be reduced. The most obvious quality that can be used for this purpose is clearly fruit colour, and in the past it was on this basis that graded ripening series of tomatoes have been selected for studies on fruit composition in the Chemistry Department. As a second characteristic for study some measurement of firmness would seem useful. The merits of a number of pressure testers or penetrometers for measuring the firmness of tomatoes and other fruit were reviewed by Hamson (1), who subsequently used one such device for selecting firm-fruited varieties of tomato in breeding experiments. More recently, Kattan (2) briefly described a "Firm-o-meter" which had the advantage that not only were the results shown to be independent of the size of the fruit but also the instrument exerted a constrictive force round the fruit rather than at one point on the surface. The purpose of this note is to illustrate the construction of a somewhat modified form of the apparatus in greater detail, and also to present some of the results obtained. It should be pointed out, however, that the basic design and method of operation are due to Kattan.

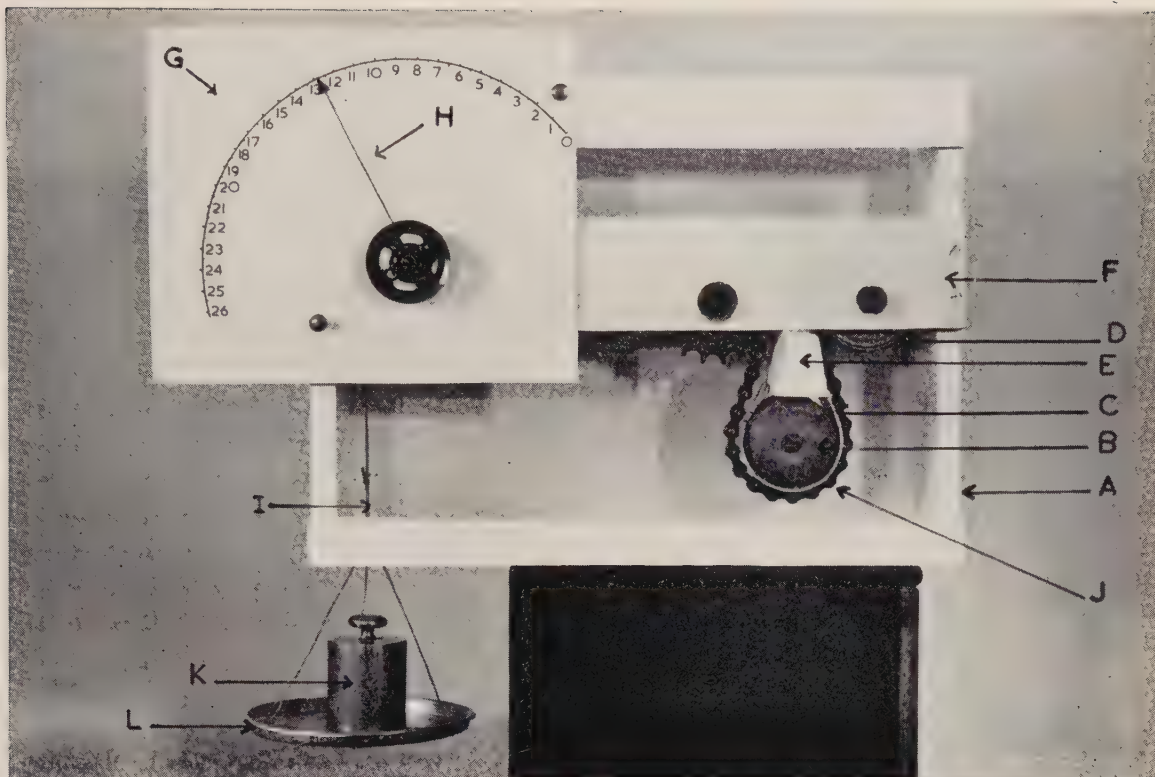
### Experimental

#### *Firmness index*

An illustration of the apparatus, including details of construction, with the front frame removed, is shown in the Plate. One end of the chain is firmly attached to the framework at point F, from which point it passes over a sprocket before encircling the fruit and fitting over a second ballbearing sprocket. The free end of the chain is fastened to a strong but flexible wire which runs over a grooved pulley bearing the pointer and thence to the weight pan. For the investigations in progress it was essential to avoid damage to the fruit during the measurement of firmness and prior to chemical analysis. No provision was made for this in the apparatus originally described by Kattan, but the difficulty was overcome by placing a flexible band (consisting of 34 pieces of aluminium strip each  $4 \times 0.5 \times 0.2$  cm. thick, set slightly apart on a 2 cm. wide plastic tape) between the fruit and the chain. With the fruit in position against the wooden block E and 500 grams on the weight pan, the pointer was set between 0 and 1 on the scale and the exact reading taken when steady. The load was then increased to 2000 grams and the difference in readings recorded after 30 seconds. A "blank" value, obtained by placing a range of incompressible cylinders between 4 and 8 cm. in diameter (the limits of the instrument) in the machine and averaging the readings so obtained, was subtracted from all results; this small correction arose from the slight stretching of the wire and chain under load.

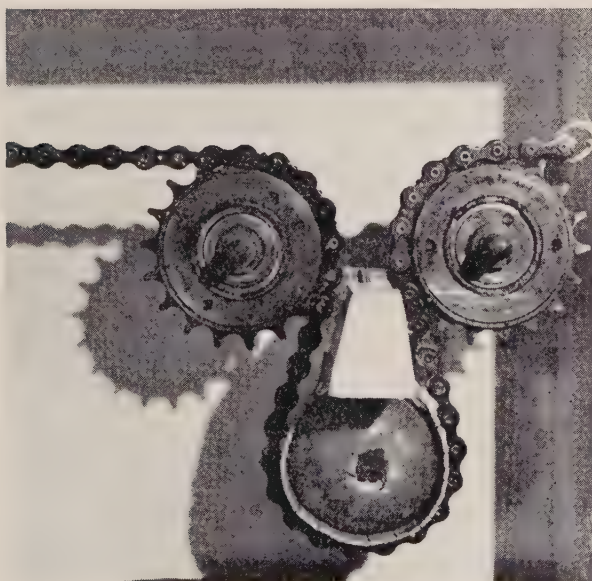
It was found that more consistent results could be obtained if the firmness index was taken as the mean of the last four of five readings made at equidistant points round the perimeter of the fruit, the original position being selected at random.





*Key to upper photograph*

- A. Wooden frame
- B. Tomato fruit under test
- C. Flexible aluminium belt
- D. Ball bearing sprockets
- E. Wooden projection against which the tomato is compressed
- F. Point of attachment of one end of the chain
- G. Scale
- H. Pointer
- I. Flexible wire attached to the chain and passing over a grooved wheel
- J. Link chain
- K. 2000 gm. weight
- L. Weight pan



*Left:* Enlargement of the sprockets

APPARATUS FOR MEASURING THE FIRMNESS OF TOMATO FRUITS (after Kattan 1957)



## Colour Index

Five arbitrary yet clearly recognisable colour grades were chosen to exemplify a ripening series:—

### Stage 1. Green

“Mature” fruit (i.e., full weight per individual) without any trace of yellow colour either externally or round the seeds when subsequently cut open, taken from trusses on which other fruit had already begun to ripen.

### Stage 2. Green-orange

Predominantly green but with distinct yellow or yellow-orange colour at the blossom end, especially along the line of the septa.

### Stage 3. Orange-green

As nearly as possible half green and half orange in colour.

### Stage 4. Orange

A pure orange colour overall with no trace of green pigment.

### Stage 5. Red

As far as possible the uniform red colour of fully ripe fruit.

## Results and discussion

The results for the firmness index, measured on the apparatus shown in the Plate, are given in Table I. The data consist of nine graded series of fruit of variety ‘Potentate’ and four series of variety ‘Immuna’, each series including five stages of ripeness as defined above. In each graded series the numerical values increase from the green to the red stage, indicating softening of the fruit as ripening proceeds. Statistical analysis of the figures shows that for both varieties differences in firmness index for the various stages of ripeness were highly significant; the significant differences between means at the 1% level of probability were 0.76 and 0.73 for ‘Potentate’ and ‘Immuna’ respectively. No significant differences in firmness were found between the series of fruit graded on different occasions, though ripe fruit of the variety ‘Potentate’ tends to be firmer than that of ‘Immuna’ as will be discussed subsequently.

TABLE I  
MEASUREMENT OF FIRMNESS INDEX AT VARIOUS STAGES OF RIPENESS

| Variety     | Colour Index | Series |      |      |      |      |      |      |      |      | Mean |
|-------------|--------------|--------|------|------|------|------|------|------|------|------|------|
|             |              | 1      | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |      |
| ‘Potentate’ | Green        | 5.7    | 5.9  | 4.8  | 5.8  | 6.5  | 7.3  | 6.2  | 6.3  | 6.0  | 6.1  |
|             | Green-Orange | 8.2    | 8.3  | 8.0  | 8.3  | 7.3  | 8.3  | 8.2  | 7.8  | 9.0  | 8.2  |
|             | Orange-Green | 10.3   | 8.9  | 8.4  | 9.2  | 9.8  | 8.8  | 9.4  | 9.2  | 9.3  | 9.3  |
|             | Orange       | 11.1   | 9.6  | 9.7  | 10.0 | 10.2 | 10.0 | 10.8 | 10.5 | 10.1 | 10.2 |
|             | Red          | 11.1   | 10.6 | 11.8 | 11.2 | 11.0 | 10.3 | 11.7 | 12.6 | 12.6 | 11.4 |
| ‘Immuna’    | Green        | 6.2    | 6.3  | 5.8  | 6.2  |      |      |      |      |      | 6.1  |
|             | Green-Orange | 9.0    | 8.7  | 8.1  | 8.7  |      |      |      |      |      | 8.6  |
|             | Orange-Green | 10.4   | 11.0 | 10.4 | 11.2 |      |      |      |      |      | 10.8 |
|             | Orange       | 12.2   | 12.1 | 12.2 | 12.2 |      |      |      |      |      | 12.2 |
|             | Red          | 14.2   | 14.2 | 14.0 | 13.2 |      |      |      |      |      | 13.9 |



While the data in Table I show the relationship between fruit colour and firmness index, they give no information concerning the rates of ripening. It was unfortunately not possible to study rates of ripening at the same time as the measurements of firmness were being made, since the latter were themselves only a preliminary stage to studies of enzyme activity in ripening tomato fruit. However, provided extremes of temperature are avoided, there appears to be no reason at present for believing that the form of the relationship between pigmentation and time (as distinct from actual rates of change) would vary appreciably from one trial to another. The opportunity was therefore taken towards the end of the season, when analytical studies had been completed, to study the rate of change in colour of tomato fruit. A large batch of "mature" green fruit as previously defined was accordingly selected from the same plants as were used for the previous studies, and allowed to ripen in trays in the glasshouse. The temperature range was from 15.6°C. (night minimum) to 22.3°C. (day maximum). A further batch of fruit was incubated at 26°C. in the dark. Complete records were kept of the colour of every fruit each day until ripe. From the extensive records thus accumulated, average values were calculated for the time taken for fruit of each variety to pass from one ripening stage to the next; the results are given in Table II.

TABLE II  
THE MEAN TIME IN DAYS BETWEEN SUCCESSIVE RIPENING STAGES OF TOMATO FRUIT

| Variety     | Storage     | Green<br>Green-Orange | Green-Orange<br>Orange-Green | Orange-Green<br>Orange | Orange<br>Red | Total |
|-------------|-------------|-----------------------|------------------------------|------------------------|---------------|-------|
| 'Potentate' | Glasshouse* | 9.2                   | 1.8                          | 0.9                    | 3.6           | 15.5  |
|             | Incubator†  | 7.3                   | 1.3                          | 0.7                    | 2.8           | 12.1  |
| 'Immuna'    | Glasshouse* | 8.1                   | 1.5                          | 0.8                    | 3.0           | 13.4  |
|             | Incubator†  | 6.9                   | 1.1                          | 0.6                    | 2.4           | 11.0  |

\*Night minimum 15.6°C., day maximum 22.3°C. Fruit ripened in diffuse daylight in September.

†Set at 26.0°C.

The results indicate that the rate of ripening between certain of the stages of pigmentation already defined was relatively rapid, particularly from orange-green to orange. In contrast, the average time elapsing before mature green fruit showed any yellowness was relatively long. It must be noted, however, that the mature green stage cannot be defined or selected with the same degree of precision as the remaining states of pigmentation. Fortunately the primary object of the present studies concerns changes in biochemical activity and composition accompanying the development of orange and red pigments in the fruit, and hence the uncertainty concerning the green fruit is not of major importance.

Whilst it has been emphasized that the data from Tables I and II were obtained at different times and under different conditions of ripening, it is of interest to relate the two sets of results. It is clear that fruit of the variety 'Immuna' not only ripen more quickly than 'Potentate' but are also softer at each colour stage.

It is suggested that measurements of firmness could give useful information concerning the state of ripeness at which different varieties of tomato should be picked, with subsequent extension, if necessary, to follow the fruit through the normal channels of marketing and distribution.

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## 6. A REVIEW OF THE LITERATURE RELATING TO STANDARD SEED AND POTTING COMPOSTS

by

P. J. SUTTON

The increasing use of standardized seed and potting composts for a very wide range of plants has been a major feature of British glasshouse practice for almost twenty years. This has also been true of German and Californian horticulture since World War II. During 1958 interest in the problems of composts was increased by the publication in the U.S.A., in 1957, of "The U.C. (University of California) system for producing healthy container-grown plants" (8). In this manual the use of sand, peat, or mixtures of the two for raising seedlings and for the bench and pot cultivation of plants is advocated. Dempster (11) has also recently published the results of his work in this country on the use of a mixture of sand, peat and clay for raising seedlings and growing pot plants.

This interest has arisen largely because of a difficulty inherent in the widely-used John Innes composts, namely the use as a basic constituent of turf loam defined within limits which are in many places difficult to satisfy. In other countries soil and climatic conditions different from those in England often accentuate this problem. The shortage of turf loams suitable for the John Innes composts has stimulated investigators in the U.S.A. (8, p. 91), Germany (15) and Switzerland (12) to study the use of other more readily available materials as a basis for composts.

It is proposed in this review to survey the literature relating to the John Innes composts (which appear to be the only standard composts in which loam is a constituent), mixtures of sand and peat, composts including clay, and composts including vermiculite. It is not at present intended to deal with the nutritional aspects of seed and potting composts, and the recommended additions of fertilizers and lime to the various composts will not normally be described.

Two general observations must be made. Firstly, no fundamental studies on the precise requirements of plants with respect to the physical properties of seed and potting composts have been made. The development of most standard composts has proceeded from a consideration of the physical and chemical characteristics of possible compost constituents in relation to their effect on plant growth. Recent work at the John Innes Horticultural Institution has been of a more fundamental nature, but is confined to composts according to the John Innes formulae (46, 47).

Secondly, there is little comparative information on plant behaviour in different standard composts. Only one statistically valid series of experiments to obtain such information appears to have been carried out (21).

### The John Innes composts

Following a serious loss of plants of *Primula sinensis* owing to a wilt disease at the John Innes Horticultural Institution during 1933, partially sterilized soil was used as a precautionary measure for the 1934 crop. Poor germination and unsatisfactory seedling growth resulted (49, p. 9). Lawrence and Newell, failing to find an explanation for this, carried out a large number of tests on the various ingredients used for composts, including pH determinations, seed-germinating capacity, and the effect of steam sterilization on germination and seedling growth. A standard sterilized compost was adopted in 1934 "giving definitely superior results" (25).

However, poor germination and seedling growth again occurred in a number of cases, notably with *Primula sinensis* and verbena hybrids. Investigations led to the conclusions that lime must not be added before sterilization, sterilization of the constituents must be done separately before mixing, phosphates must be added to sterilized soil, and drainage in sterilized soil must be improved, e.g., by the addition of sand. Partly on the basis of these results, a 5:4:2 mixture of loam, sphagnum peat and sand was proposed as a compost for sowing and pricking-out, and a 5:4:1:1 mixture of loam, sphagnum peat, sand and ballast for potting. Both these composts were found to compare favourably with unsterilized composts (26, 48).

During 1936 and 1937 further experiments were made in a study of soil sterilization and composts (27, 28). In 1937 the formulae of the John Innes composts as we know them today were published, save only that the addition of chalk was given as 1oz. per bushel, instead of the  $\frac{3}{4}$ oz. recommended now. Some of the conclusions reached at this time have since been modified; for example, it was claimed that good results could be obtained in a compost of poor physical condition by the addition of phosphates, and that the quality of the loam was "not of the first importance if fertilizers were added" (28).

The John Innes Seed Compost (JIS) and the John Innes Potting Compost (JIP) consist of loam, peat and sand in the ratios 2:1:1 and 7:3:2 respectively. Recent recommendations advocate the use of a medium-heavy loam (clay content about 25%) with a pH of 5.5–6.3. The loam should be prepared for use in composts by stacking turves cut from a well-managed pasture or long-term ley and allowing them to rot for about six months. Additions of lime, phosphate, potash and strawy manure should be made during stacking as necessary (46, 51). The peat should be granulated or fibrous, relatively undecomposed, either sedge or sphagnum, and with a pH not less than 3.5. The sand should be clean and coarse, 60–70% of the particles being  $\frac{1}{8}$  in. –  $\frac{1}{4}$  in. in diameter (49).

In 1939 appeared the first edition of Lawrence and Newell's "Seed and Potting Composts" (49), in which their work of the preceding five years on soil sterilization and composts was presented.

From 1943 to 1951 numerous experiments were carried out in a study of the effects of seedling treatments on the growth of plants in JI composts and subsequent crop yields (29, 30, 31, 32, 33, 34, 35, 37, 38, 40). A few further experiments of this kind were also conducted from 1953 to 1955 (42, 43, 44). Among the results in 1946 and 1947 were recommendations for the optimum sequences of JI composts for various plants as growth proceeded (33, 34).

During 1946 comparative trials with JI composts and fifteen different growers' composts provided a revealing comment on the suitability of the numerous composts then in use (33). In only one of the fifteen composts were tomato plants as good as in JIP no. 1. In only four were they as good as in JIS, which is not in any case a recommended compost for the pot stage in tomato propagation.

Also in 1946 Lawrence (33) wrote of the importance of standardizing the loam ingredient of the JI composts. Recognizing the fact that some growers were being obliged to use inferior loams, recommendations were given for adjusting the pH of acid loams and the phosphate status where this was very low. Further recommendations were given in 1948 (36) in which the addition of a 2in. layer of strawy manure to alternate layers of the loam stack was advised for the first time. This was found to improve the "composting" of the loam in the stack and the quality of the composts made from it. These recommendations are in contrast to the earlier conclusions regarding the loam constituent of the composts (28). The assessment of suitable loams for JI composts was discussed by Pizer and Pearl in 1954 (51).



As ordinary JI composts were found unsuitable for calcifuge species, Alvey at the John Innes Horticultural Institution investigated, during the period 1951–1956, the use of flowers of sulphur as a substitute for chalk in the composts. The work was at first confined to *Erica nivalis* and *E. gracilis*. By 1954 the work on ericas was complete. An acid JIS in which the chalk had been replaced by the same quantity of flowers of sulphur ( $\frac{3}{4}$  oz. per bushel) gave better growth than a grower's compost, a 6:1 mixture of rhododendron peat and Cornish sand, and chlorosis did not occur (4, 39, 41, 42, 43). The modified JI compost was called JIS(A). Subsequently, two varieties of azalea grew and flowered satisfactorily in JIS(A), and *Rhododendron ambiguum* and *R. obtusum* also germinated and grew well (44, 46).

An experiment in 1951 in which carnations, traditionally lime-loving plants, were grown in JIP no. 2 and JIP no. 3 in which limestone chippings replaced sand showed that better growth was obtained in unmodified JI composts (39).

During 1952 and 1953 the soil conditioner Krilium C.R.D. 189 was used as a substitute for peat and sand in JI composts, and as an additive to the composts. Comprehensive experiments showed no advantage in its use (41, 42).

Bunt has studied several physical and chemical properties of the JI composts, including *pH* changes (9, 44).

The beneficial effect of leys on the growth and yield of crops when the land is subsequently ploughed has been recognized for centuries. In view of the shortage of suitable loams for composts, Alvey commenced experiments during 1955 to compare the effects on germination and growth of preparing JI composts with loams of similar mechanical analysis from arable soil and from old pasture soil. Inconsistent results were obtained for the germination and early growth of antirrhinum, primula and tomato (47).

To study these effects more closely, grass leys were sown on soils with three different clay contents. Four grass species were used, and some fallow plots were kept hoed for comparative purposes. By 1957 grassing-down as compared with fallowing and regular hoeing had significantly increased the percentages of water-stable aggregates in the soils. However, no significant differences in the weights of plants grown in composts made from these soils were observed. The experiment is continuing (46, 47).

No standard composts have received such extensive testing in both experiment and commercial practice as the JI composts. Over 180 species, diverse both botanically and horticulturally, are listed as having been successfully grown in them by Lawrence and Newell (49, p. 142), and the list is stated to be incomplete.

### **Mixtures of sand and peat as composts**

The concept of mixtures of sand and peat as media for the cultivation of plants is not a new one and perhaps arose as a natural result of the possibilities shown by sand culture. Sand culture received attention for purposes of practical crop production from the 1920's onwards (4, p. 122).

As Laurie (23) pointed out in 1932, sand itself, though shown by his experiments to be a satisfactory growing medium for quite a wide range of ornamental plants, is too heavy for a satisfactory potting medium, and not cohesive enough for potting on. Additional disadvantages are its poor moisture retention, especially in hot weather, and the necessity for carefully controlled nutrient applications.

Peat itself has been used successfully for growing gloxinias and *Primula malacoides* by Deshusses and Duperrex (12). The U.C. mix "E" is also peat alone, and suggested uses are the cultivation of azaleas, gardenias and camellias (8). Very recently the successful use of coarse peat as both a propagation and a growing medium for certain foliage plants in Germany and in England has been reported (54).

Commencing in 1928, Laurie (22) grew a range of annual plants in sand, in 1:1 mixtures of sand and manure, and sand and peat, and in 2:1:1 mixtures of sand, manure and peat; mixtures containing peat were duplicated by the separate use of both sphagnum and sedge peats. The particle diameter range of the sand was not stated. Results where organic matter was present in the media were better than where sand alone was used, and were mostly comparable with those obtained in soil.

In 1931 two varieties of chrysanthemum were also grown in sand and in a sand:peat mixture (ratio not stated), each with either organic or inorganic fertilizers. The results were similar in all cases, and were also similar to those obtained in soil (22). Later, carnations were grown in a compost (not described), in a 1:1 mixture of sand and peat, and in sand. Results were at least as good in sand and the mixture as in the compost (23). Among Laurie's conclusions were that roses, chrysanthemums, carnations, antirrhinums, stocks and calendulas could be grown satisfactorily in a 1:1 mixture of sand and peat to which periodic applications of dry fertilizers were made (23).

For almost twenty years after Laurie's experiments the use of sand:peat mixtures appears to receive no further attention in published literature. Neither Laurie and Kiplinger in 1944 (24) nor Post in 1956 (52) mention it.

However, in 1952 Deshusses and Duperrex (12) working at the Laboratoire de Chimie Agricole, Geneva, described experiments in the use of mixtures of sand and peat (among others) for begonia 'Gloire de Lorraine', gloxinia, *Primula malacoides*, *P. obconica* and *P. sinensis*. Preliminary studies were made of the chemical and physical properties of ten peats obtained from six different localities. Mixtures of selected peats, heath soil, turf loam, leaf mould, garden compost and sands were formulated for the experiments. The percentage total porosity, percentage capillary porosity and percentage non-capillary porosity were determined for each compost, both before and after plants had been grown in it.

The composts in which the plants made the most satisfactory growth were mainly mixtures of peats, some with the addition of calcareous sand. A correlation appeared to exist both between growth and total porosity and between growth and the proportions of capillary and non-capillary porosity. For example, it was suggested that if begonia 'Gloire de Lorraine', gloxinia, *Primula malacoides* and *P. obconica* were grown in a medium of the same total porosity, gloxinias would grow best in a fast-draining medium retaining a low proportion of capillary water, while the other plants would grow best in a medium with a high content of capillary water. *Primula sinensis* would thrive better in a medium of lower total porosity than any of these plants.

Deshusses and Duperrex nevertheless suggested that a wide range of plants could be grown satisfactorily in a standard 1:1 mixture of granular peat and fibrous peat to which is added 5-7% of calcareous sand. They had grown bulbs, hydrangeas and various foliage plants in this compost with great success.

Hartman-Dröge (16), working in the Netherlands on four different composts (not mixtures of peat and sand), failed to show a definite correlation between the physical properties of the composts and the growth of cyclamen in them. In neither the Swiss nor the Dutch work, however, could nutritional effects of the various composts on plant growth be discounted.

In 1953, Asen and Wildon, at the Michigan State College Agricultural Experiment Station, U.S.A., reported an experiment in the bench cultivation of chrysanthemums in a 1:1 mixture of sand and peat. The investigation was primarily on nutritional requirements in such a compost, and appeared to be an attempt to follow up Laurie's work over twenty years earlier. Optimum growth in the mixture, obtainable by appropriate nutritional treatment, was superior to that in soil (6).

The U.C. composts appear to have evolved quite independently of the work of Laurie and of Asen and Wildon (8, p. 93). Owing to the scarcity of suitable turf for the adoption of the JI composts in California, investigations were begun in the Department of Plant Pathology, University of California, Los Angeles, in 1941 to find a better compost than those in use. Matkin, Chandler and Baker also criticized the JI composts on the grounds of variability, the necessity for composting the turf, and the deleterious effects on germination and early growth of certain species following steaming (8, p. 93; but see also 49, p. 79).

At first a 10:2:2 mixture of fine sandy loam, leaf mould and horse manure was used. Peat was soon substituted for the organic materials, and the compost became a 7:3 mixture of sandy loam and peat (7). Subsequently this was amended by the addition of two parts of very coarse sand or crushed rock or pea gravel grading up to  $\frac{1}{4}$ – $\frac{1}{8}$  in. in diameter. The ratio 7:3:2 is that of the John Innes Potting Compost, but the constituents are somewhat different.

These two composts approximate to the current U.C. compost "B", since the sandy soils used as a basis for these composts may also be used in U.C. composts.

Finally, following consideration of various possible compost constituents and the importance of their characteristics in growing media, the U.C. composts were formulated. There are five of these, consisting of fine sand alone, sphagnum peat alone, and combinations of the two in the ratios 3:1, 2:2 and 1:3 (8, sections 5 and 6).

Fine sand for this purpose is defined as of particle diameter 0.05–0.5mm.; the percentage of coarse sand present where the fine sand is impure should not exceed 12–15%, nor should the silt and clay fractions together exceed 15%. In California certain soils very high in fine sand content are widely used and are very suitable for use in U.C. composts. For sphagnum peat, sawdust, wood shavings, ground bark and rice hulls may be substituted in whole or in part.

Grower experience with U.C. composts at various stages in their development appears to have been extensive in California. Bedding plants, vegetable seedlings, pot and foliage plants, woody nursery stock, bench or bed-grown gardenias, roses, carnations and cymbidiums have all been cultivated commercially in U.C. composts. Results have compared very favourably with those in traditional composts in which clay loam was commonly a constituent (8, p. 263).

A recent paper provides independent corroboration of the feasibility of growing plants satisfactorily in sand:peat mixtures. Erickson and Wedding (13), working at the University of California Citrus Experiment Station, carried out pot experiments on the frequency of mineral applications to five media in the greenhouse production of nine different species. The media were water, sand, vermiculite, a 1:1 mixture of sand and peat, and a 1:1:1 mixture of soil, sand and peat. The plants were bean (*Phaseolus vulgaris* 'Red Kidney'), cabbage, melon, lettuce, tomato, cotton, sorghum, sugar-beet and lemons.



Considering only the two mixtures, the mean fresh weight of sorghum was significantly greater in the mixture of sand and peat for the daily frequency of mineral application. The mean fresh weights of beans and cotton averaged over all frequencies of application were also significantly greater in this medium. Only sugar beet showed significantly greater mean fresh weights in the mixture of soil, sand and peat, both for the daily mineral applications and averaged over all frequencies of application.

### Composts including clay

To the reviewer's knowledge only three standard seed and potting composts including clay have been formulated. They are Einheitserde, the German compost developed by Fruhstorfer shortly after the war; Allerton and Ray's compost, modelled on Einheitserde but also incorporating vermiculite, which will be described in the following section of this review; and a new compost independently formulated by Dempster.

Fruhstorfer (15) first developed a potting compost in 1934, comprising arable soil and peat; this proved useful for raising cucumbers, but not for general purposes. Although aware of the work of the John Innes Horticultural Institution, he decided that turf loam should be excluded as the basis of a standard compost under German conditions (no particular reason was stated in the paper under review, or elsewhere), and that decomposable organic matter, sand, hoof and horn meal and chalk should also not be used. His desiderata for a standard compost were water-stable crumb structure throughout the growing period, exclusion of bacterial life, low pH, exclusive use of substances which can retain nutrients and water, and tolerance to over-watering. He also sought constituents which were available in large uniform deposits in order to facilitate central preparation of the compost.

In 1946 he devised the current formula of a 1:1 mixture of granulated clay and peat, to which inorganic fertilizers were added. Minor variations exist in the literature concerning the precise composition of Einheitserde. Fruhstorfer successfully applied in 1949 for a British patent for the compost, though not under its German name. In the patent specification (14) it was stated that the clay should be heavy, forming stable crumbs, preferably taken from the subsoil, and be practically free from humus, bacteria, and weed seeds. Alternatively a mixture of sand and clay could be used. After granulation the clay and peat should be screened to a particle diameter of  $\frac{1}{8}$ – $\frac{1}{2}$  in., according to the compost's projected use. All types of peat could be used. No lime was added.

Maatsch (50), in an address reported in 1952, describes two types of Einheitserde, Pikiererde or P-Erde, for sowing and pricking off, and Topferde or T-Erde, for potting or transplanting. The two composts differ only in that 4kg. of fertilizers per cubic metre are added to the former and 8kg. to the latter.

Hülsmann and Thiele (20), writing in 1953, described the Einheitserde used in their experiments at the Versuchsgärtnerei Kleefeld in Hanover as consisting of clay, black peat and "white peat" (Weisstorf) in the ratio 2:1:1. P-Erde was described as containing 3% fertilizers (presumably by weight), and Maatsch's T-Erde was described as E-Erde, Endtopferde, containing 6% fertilizers. The pH was about 5.5, and remained stable during use.

It appears that most of the Einheitserde used is manufactured centrally and not made up by nurserymen themselves. Maatsch (50), in 1952, said that there were six factories making it, and their products were tested against a standard at the Institut für Torfforschung in Bad Zwischenahn. Fruhstorfer (15) himself warned nurserymen against trying to make it, as difficulties

and risks of failure attended attempts. This is borne out by Allerton's experiences in attempting to make it in England, in which he found the clay he used was unsuitable (1) and varied widely in phosphate-fixing capacity, with serious results (2). Suitable types of clay are not easily found (5) and are absent from large areas of Germany (53). In Germany Einheitserde is considerably cheaper than other composts (53). The centralized preparation of a highly uniform compost at a small number of factories is in many ways an ideal solution to the problem of composts for nursery use.

Einheitserde requires rather different handling from other composts. It should be used as dry as possible for pricking-out and potting (19), and must not be firmed during these operations but left to settle after watering (20). Heavier watering is necessary than for ordinary composts, and it is important not to let it dry out. There is no risk of over-watering because of the stable crumb-structure and the absence of decomposable organic matter and organisms capable of commencing a rotting process (20). This lends itself to the mechanization of watering (50).

Einheitserde has been extensively tested in Germany. The first trials were conducted at Weihestephane in 1947 and 1948. The composts proved weed- and disease-free, suitable for propagation from seeds and cuttings as well as for growing-on, and stable to watering. Plants grew more rapidly than in other composts (which were not described), and pot plants remained longer in bloom when grown in Einheitserde (15). Excellent results were also obtained at Hanover in 1948 (50).

In the period 1949-1952, tomato, cucumber, celery, kohlrabi and cauliflower seedlings and various nursery subjects (shrubs and trees) were grown in Einheitserde at the Versuchs- und Lehrwirtschaft für Gartenbau in Kiel (19). As compared with ordinary composts (not described) results were in most cases considerably superior; for celery and cauliflower they were inferior, and for other brassicas Einheitserde seemed to have no advantage.

Hülsmann and Thiele (20) reported extensive experiments with Einheitserde at the Versuchsgärtnerei Kleefeld of the Landwirtschaftskammer Hanover during 1949-1953. Einheitserde was successfully used for growing various pot plants on a pumice layer by sub-irrigation; the same method was used for germinating fine seeds, e.g., *Begonia semperflorens* and gloxinia, in pans. Under normal cultural methods *Begonia semperflorens*, cyclamen, gloxinia, hydrangea and *Primula obconica* grown in Einheitserde gave highly satisfactory results as compared with plants grown in ordinary composts (which were not described). For hydrangeas and *Primula obconica*, however, the additions of chemicals to the Einheitserde had to be modified.

In addition to experiments with these plants, a considerable range of greenhouse flowering and foliage plants was successfully grown in Einheitserde at Kleefeld. No check was observed when various popular species of pot plants, such as cyclamen, gloxinia and *Primula obconica*, were transferred from Einheitserde to ordinary composts and *vice versa*. As a result of the experiments, the Versuchsgärtnerei Kleefeld has adopted the exclusive use of Einheitserde for general purposes.

However, Lamm has carried out experiments in Sweden in which Einheitserde (T-Erde) was found to compare unfavourably with JIP no. 2 as a medium for raising tomatoes. Over the period 1954-1956 the mean total yield of fruit from plants raised in Einheitserde was over 9% lower than from plants raised in JIP no. 2; the mean yield in the first four weeks of cropping was over 20% lower (21).

Allerton (1) in England has reported that he conducted comparative tests between Einheitserde and JIP no. 2, and that Einheitserde made a favourable impression.

Dempster's work (11) on composts arose from the difficulty of obtaining suitable loam for the JI composts. In 1955 various mixtures of sand, peat and clay were tested, to which JI base and chalk were added. A mixture in the ratio 5:4:1 was selected for use in 1956. Difficulties due to drying-out and nitrogen shortage arose. More frequent watering and the application of urea and sucrose in solution as a foliar spray to bedding plants in trays filled with the mixture gave results equal to or better than in JI composts. A range of pot plants, including cyclamen and pelargonium, were also satisfactorily grown in 3½ in. pots in this mixture. The same mixture was used in 1957 for bedding plants and vegetable seedlings in trays, and for pot plants, but to it was added a base fertilizer very rich in nitrogen. Results were excellent.

In Dempster's compost the clay, which was obtained from a firm of flower pot manufacturers, was dried and powdered to particles of not more than 1/10 in. diameter; its pH was 7.8–8.0. The peat was granulated sedge peat. The sand was double-washed, silt-free, and of particle diameter 1/16–1/8 in.

### Composts including vermiculite

Vermiculite is an "exfoliated" mica, i.e., a mica heated until part of the water present in the crystal lattice volatilizes and the mineral increases greatly in volume. It has received considerable attention in a number of countries as a constituent of potting composts and as a medium for hydroponics, seed germination, and (above all) for rooting cuttings. It has a high capacity for absorbing and holding water (18).

In 1954 Allerton and Ray (3) patented a compost consisting of peat, vermiculite and clay and/or an alginate-containing material in the ratio 1–2:1–2:1–2. The peat should preferably be sphagnum moss peat. The vermiculite should be of a non-alkaline or slightly acid grade, particle diameter 1/16–1/8 in. The clay should be heavy, having a low silt and fine sand content (10–15%), and its granules should be water-stable; an experimental criterion of water-stability was given. In the example of such a compost given in the patent, the clay was granulated.

The compost has proved too expensive to manufacture (1). To the reviewer's knowledge no published information on the growth of plants in it exists.

Hayes and Simpson (17), working at the Edinburgh College of Agriculture in 1955, carried out an experimental comparison between the growth of *Antirrhinum majus* and *Salvia splendens* in JIP no. 2 and in a 2:1 mixture of JIP no. 2 and vermiculite in 5 in. pots. Flowering occurred earlier in the latter mixture, and the plants grown in it appeared superior visually. The mixture retained excellent drainage properties throughout, whereas the JIP no. 2 deteriorated rapidly and unevenly and the pots required individual watering.

Vermiculite has also been used experimentally as a substitute for peat and sand in JI composts. Results suggested that it might be satisfactory for use in pots, but not in soil blocks (41).

### ACKNOWLEDGMENTS

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## 7. THE EFFECT OF WHITE-FLY POPULATIONS ON THE CROPPING OF TOMATOES

by

N. W. HUSSEY, W. J. PARR & BARBARA GURNEY

### Introduction

For many years the Glasshouse White-Fly (*Trialeurodes vaporariorum* Westw.) has been one of the most serious pests of tomatoes grown under glass. Both the adult white-flies and immature "scale" stages feed on the foliage and, when numerous, weaken growth and induce wilting, especially in strong sunlight. The principal injury, however, is caused by the excretion of honey-dew by the adults and more advanced scale stages; this falls in profusion on foliage and fruit, and under certain conditions gives rise to the growth of a dark "sooty mould" (*Cladosporium sphaerospermum*). This mould no doubt interferes seriously with the respiratory function of the leaves, and also makes it necessary to clean the fruit before marketing. Little information is available, however, about the effect of white-fly infestations on the cropping of the plants.

Lloyd (1921) working with tomato plants (*var.* 'Kondine') growing in large pots and infested with white-flies early in May, found that those plants on which the infestation was allowed to continue unchecked produced less than half the weight of crop yielded by those on which the infestation was controlled by fortnightly fumigation. He also stated that the heavily infested plants were practically dead by the end of August, whereas the others remained vigorous until at least the beginning of October.

For future work on biological control it is important to be able to predict the probable economic effects of a given white-fly population. In view of the scarcity of such information, experiments were done to determine the effect of different levels of white-fly populations on the cropping of tomatoes. Observations are also reported later in the paper on the question of honey-dew production and the conditions under which sooty moulds grow.

### Pest assessment studies

A preliminary experiment compared the effect of heavy infestations on tomato plants for periods of up to nine weeks after potting when 2½ in. high. Four pairs of plants were treated as follows: (a) Uninfested (b) infested for 3 weeks (c) infested for 6 weeks (d) infested for 9 weeks. The infestation was brought under control after the allotted time, and the plants kept free from further invasion by the flies, by spraying weekly with 0.025% DDT emulsion. The plants were grown on until they reached the sixth truss, and the number and weight of fruit from each recorded.

The greatest effect obtained was that on height growth after nine weeks (Table I). The yield data were of little value with such a small number of plants, but those infested for nine weeks showed a marked reduction in crop weight compared with the uninfested controls which for reasons unknown cropped poorly.

In the light of this preliminary work a larger experiment was designed to investigate the effect on the crop of infesting plants at different stages of growth in relation to truss formation and to determine the incidence of sooty mould, particularly on the fruit.



TABLE I  
EFFECT OF LIMITED PERIODS OF WHITE-FLY  
INFESTATION ON TOMATO PLANTS

| Duration of infestation | Mean height of plants after 9 weeks | Mean crop weight from six trusses |
|-------------------------|-------------------------------------|-----------------------------------|
| (a) Uninfested          | <i>in.</i><br>32                    | <i>oz.</i><br>37                  |
| (b) 3 weeks             | 29                                  | 49                                |
| (c) 6 „                 | 27                                  | 72                                |
| (d) 9 „                 | 25                                  | 27                                |

### *Experimental procedure*

Tomato plants (*var.* 'Potentate') raised from seed sown on 14th March were potted into 9in. pots and set out on staging in a 100ft. glasshouse on 22nd April. These were arranged in a randomized block design comprising eight replications of five treatments with three plants in each of the 40 "plots". The treatments were as follows:

- A. Plants infested 1 May, 1958—1st truss in flower
- B. „ „ 30 May, 1958—4th „ „ „
- C. „ „ 20 June, 1958—6th „ „ „
- D. „ „ 18 July, 1958 —6th truss starting to ripen
- E. „ „ not infested.

The plants in treatments A, B & C were infested by liberating on the leaves of each some 200 adult flies collected from infested stock plants. Those of treatment D were colonized from neighbouring plants which by that time had developed a high population.

The plants were kept free from white-fly until the required time by spraying weekly with 0.025% DDT emulsion to within ten days of the date on which they were to be infested. This gave sufficient time for the DDT deposit on the foliage to become innocuous to the flies. The uninfested control plants were similarly sprayed throughout the experiment. Screens were used during spraying to prevent spray drift from plant to plant. The fact that the plants had to be grown on staging made it necessary to limit the growth of the plants to seven trusses. Consequently the main stem was stopped on 17th June, eight weeks after the final potting. To ensure young green foliage for the flies in the later stages of the experiment, lateral shoots between the fifth and seventh trusses were allowed to develop. At intervals during the experiment estimates were made of the level of population on each plant. The method of sampling was to cut a disc  $\frac{3}{4}$ in. in diameter from a single leaflet on each of two comparable leaves at different heights within the apical zone of each plant. The total numbers of eggs and scales were then counted under a low power binocular microscope. In all, four such samplings were made, the final one at intervals during August as the plants in each of the treatments successively reached an advanced stage of senescence.

The number and weight of fruit picked from each of the trusses 1-6 on each plant was recorded, together with the number of fruits contaminated with sooty mould.

Throughout the experiment cultural operations conformed to those normally carried out in commercial practice.

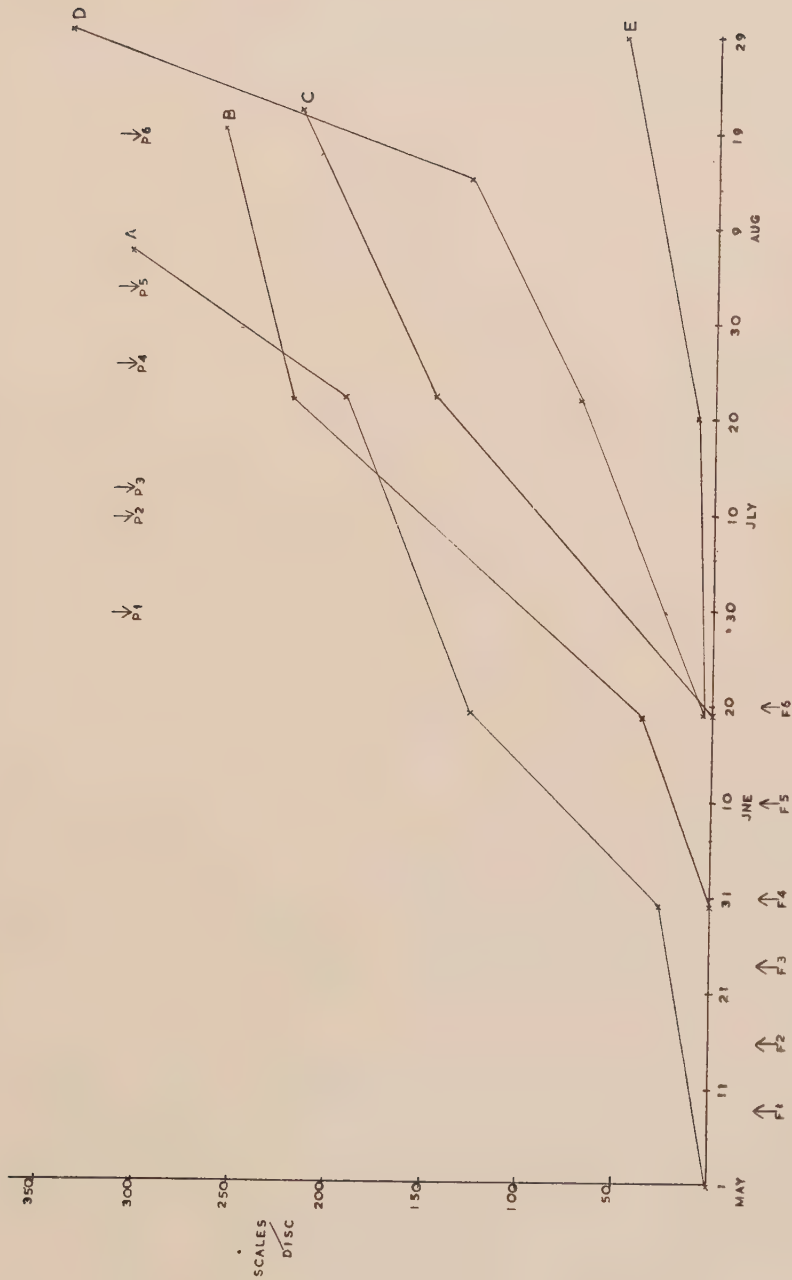


FIGURE 1  
Mean white-fly populations on different sampling dates (F<sub>1</sub>-F<sub>6</sub> mean flowering dates for trusses 1-6,  
P<sub>1</sub>-P<sub>6</sub> mean picking date for trusses 1-6)

## Results

The aim of the experiment was to obtain a range of white-fly populations on the plants during the growth of each truss. The populations on the different treatments were significantly different, except at the final counts (Table II). By that time many of the plants were dead or dying, so that plants which a few days before were carrying large populations gave unexpectedly low sample counts. When the mean numbers of scales per disc for each treatment were plotted in relation to the mean dates of flowering and picking for each truss (Figure 1), it was possible to extract data showing the mean white-fly population on each treatment during the development of a particular truss (Table III).

TABLE II  
MEAN WHITE-FLY POPULATIONS PER PLOT

| Treatment<br>Date | A     | B     | C     | D     | E   | Difference<br>significant<br>at 5 % |
|-------------------|-------|-------|-------|-------|-----|-------------------------------------|
| 30 May, 1958      | 199   | 0     | 1     | 0     | 0   | 49.4                                |
| 19 June, 1958     | 738   | 220   | 45    | 29    | 38  | 145.8                               |
| 22 July, 1958     | 1,142 | 1,320 | 895   | 411   | 73  | 247.3                               |
| Final counts      | 3,719 | 3,145 | 2,619 | 4,091 | 599 | 3,911.4                             |

TABLE III  
MEAN WHITE-FLY POPULATION DURING  
DEVELOPMENT OF TRUSSES (SCALES/DISC)

| Truss<br>Treatment | 1  | 2  | 3  | 4   | 5   | 6   |
|--------------------|----|----|----|-----|-----|-----|
| A                  | 80 | 92 | 98 | 125 | 180 | 220 |
| B                  | 47 | 75 | 83 | 115 | 129 | 150 |
| C                  | 22 | 45 | 51 | 78  | 87  | 110 |
| D                  | 12 | 21 | 24 | 38  | 49  | 95  |
| E                  | 3  | 4  | 4  | 7   | 12  | 22  |

The yield data (Table IV) did not show significant differences until the fourth truss, and even then the effects were confined to the two most severe infestations. In treatment A, the sixth truss failed almost completely; on only three plants did this truss produce normally and on nine others only one, or at most two, small fruits were produced.

TABLE IV  
MEAN YIELD PER TRUSS (IN OZ.)

| Truss<br>Treatment | A    | B    | C    | D    | E    | Difference<br>significant<br>at 5 % |
|--------------------|------|------|------|------|------|-------------------------------------|
| 1                  | 78.8 | 88.6 | 93.1 | 92.8 | 91.9 | 30.8                                |
| 2                  | 51.0 | 59.1 | 55.1 | 57.8 | 58.1 | 11.8                                |
| 3                  | 43.7 | 49.1 | 49.4 | 55.6 | 49.6 | 8.3                                 |
| 4                  | 25.9 | 36.1 | 41.2 | 39.8 | 38.4 | 6.3                                 |
| 5                  | 30.3 | 37.3 | 52.5 | 41.7 | 52.4 | 12.2                                |
| 6                  | 8.0  | 26.8 | 41.7 | 39.6 | 38.9 | 10.4                                |



The calculated percentages of fruit affected by sooty mould (Table V) showed that the controls were significantly less affected than any of the infested treatments.

TABLE V  
PERCENTAGE FRUIT AFFECTED BY SOOTY MOULD

| Treatment<br>Truss | A    | B    | C    | D    | E    | Difference<br>significant<br>at 5% |
|--------------------|------|------|------|------|------|------------------------------------|
| 1                  | 83.9 | 19.9 | 1.0  | 0    | 0    | 10.9                               |
| 2                  | 91.5 | 61.4 | 3.1  | 2.7  | 2.7  | 30.4                               |
| 3                  | 93.3 | 83.5 | 23.0 | 2.6  | 5.4  | 10.9                               |
| 4                  | 94.1 | 89.4 | 46.5 | 8.1  | 8.0  | 15.6                               |
| 5                  | 86.5 | 83.1 | 42.6 | 17.7 | 10.1 | 15.0                               |
| 6                  | 81.8 | 69.4 | 48.0 | 27.3 | 12.7 | 43.0                               |

In Figure 2 the mean crop yield per plant in each treatment and the percentage clean fruit is plotted against the white-fly population. From this graph (and Table VI) it is evident that quite low infestations, of the order of 10 scales per disc, caused losses from sooty mould, but that yield did not decrease until the population rose to about 70 scales per disc.

TABLE VI  
MEAN NO. OF SCALES PER DISC AND  
THE ECONOMIC YIELD OF TREATMENTS

| Treatment | Scales/disc | Mean wt. fruit<br>per plant | Clean<br>fruit | Economic yields<br>per plant |
|-----------|-------------|-----------------------------|----------------|------------------------------|
|           |             | oz.                         | %              | oz.                          |
| A         | 133         | 79                          | 13.2           | 10.3                         |
| B         | 100         | 99                          | 32.1           | 31.6                         |
| C         | 66          | 111                         | 72.6           | 81.0                         |
| D         | 40          | 109                         | 90.3           | 98.4                         |
| E         | 9           | 110                         | 93.5           | 102.9                        |

Measurements of the plants taken at the time of stopping showed that height growth had not been affected, at least during the initial stages of infestation. The average height of the plants in each treatment at this time ranged from 48-49 inches.

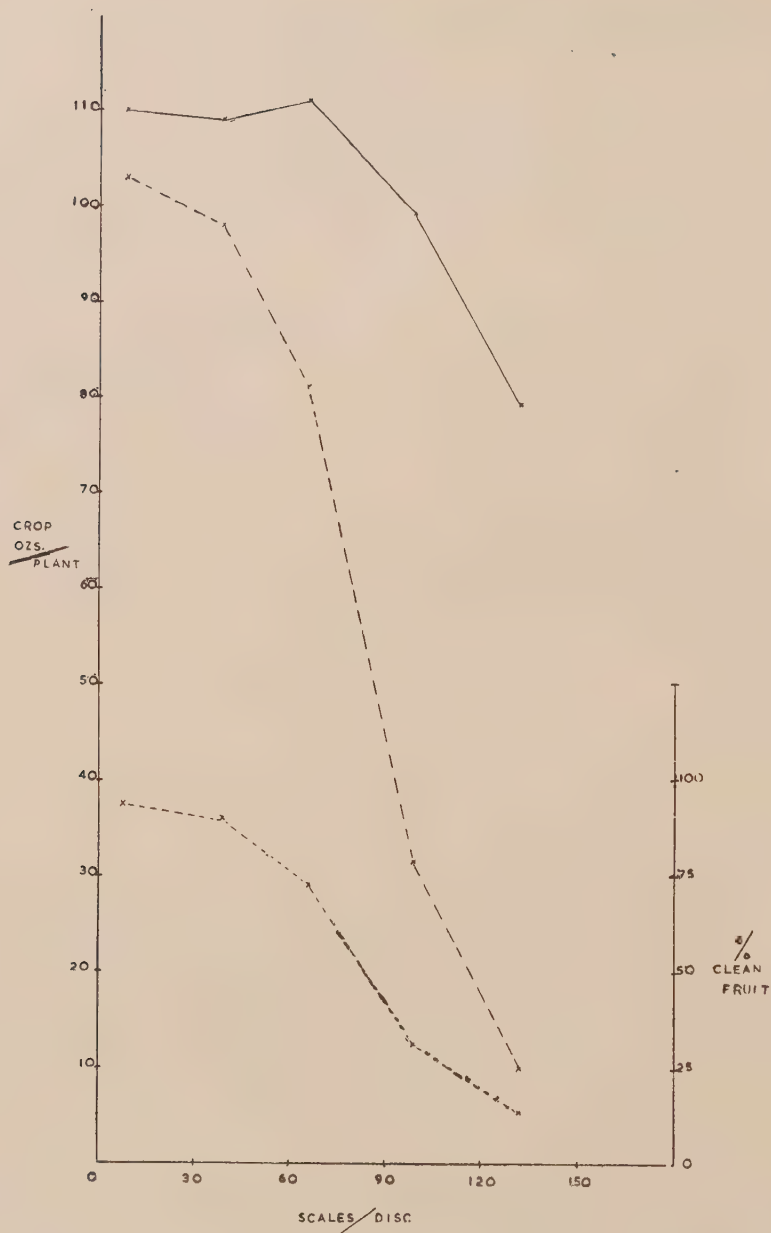


FIGURE 2

Economic effects of different white-fly population (mean populations from initial infection to final picking)

|             |    |    |                        |
|-------------|----|----|------------------------|
| Solid line  | .. | .. | Total crop (oz./plant) |
| Broken line | .. | .. | Clean crop (oz./plant) |
| Dotted line | .. | .. | % Clean fruit          |

Observations on the production of honey-dew by *Trialeurodes*

After fifty-eight adult white-flies had settled on the underside of tomato leaflets in the laboratory the droplets of honey-dew ejected by them were trapped on clean glass sheets held about half an inch below the leaflet for periods of up to five hours. The mean production of honey-dew was 10 droplets per adult per hour. The average diameter of the droplets was 0.2mm. (area 0.03 sq.mm.), so that in one day an adult could produce sufficient excretion to cover 7.2sq.mm. of leaf, and in an average life-span of 20 days one quarter of an apical leaflet could be coated by a single fly.

Second and third instar larvae produced smaller droplets (area 0.01sq.mm.) at a rate of 8 per larva per hour, but in the pupal instar droplet production reached 25 per pupa per hour and the droplets were of the same size as those produced by the adults.

Assuming that a female white-fly produces an average of 120 eggs during her life the amount of honey-dew produced by her progeny during their development would be sufficient to cover a total leaf area equal to that of twenty average size leaflets.

Environmental conditions predisposing to mycelial growth of sooty mould (*Cladosporium sphaerospermum*)

Early in the growing season it was noticed that unenclosed tobacco plants growing in a glasshouse and heavily infested with white-fly were covered with honey-dew and yet no sooty mould was present, whereas similar plants in cages were heavily attacked by this fungus. To test whether humidity was the limiting factor the following experiment was set up.

Clean glass slides were exposed below leaves very heavily infested with white-flies for one hour. They were then covered with spores of *C. sphaerospermum* by the method of Hart and MacLeod (1955). Three replications of four inoculated slides, two with honey-dew and two without, were maintained in sealed vessels over a range of sulphuric acid solutions at 75°F., giving humidities of 100%, 90%, 85% and 80%, for 72 hours. The results in Table VII suggest that a relative humidity of about 90% is necessary to initiate spore germination.

TABLE VII  
EFFECT OF HUMIDITY AND PRESENCE OF HONEY-DEW ON  
SPORE GERMINATION OF *Cladosporium sphaerospermum*

| R. H.<br>(%) | Mycelial growth on exposed slides |    |    |    |    |    |                   |   |   |   |   |   |
|--------------|-----------------------------------|----|----|----|----|----|-------------------|---|---|---|---|---|
|              | With honey-dew                    |    |    |    |    |    | Without honey-dew |   |   |   |   |   |
| 100          | ++                                | ++ | ++ | ++ | ++ | ++ | +                 | — | — | + | — | — |
| 90           | +                                 | +  | +  | +  | +  | +  | —                 | — | — | — | — | — |
| 85           | —                                 | —  | —  | —  | —  | —  | —                 | — | — | — | — | — |
| 80           | —                                 | —  | —  | —  | —  | —  | —                 | — | — | — | — | — |

++ Strong growth    + Weak growth    — No growth

In the normal diurnal cycle of humidity in a glasshouse it is reasonable to suppose that such high humidities only occur with consistency at night. Inoculated slides were therefore maintained at 90% R.H. for different periods and removed to atmospheric humidity within the incubator at other times. In observations extending over 72 hours, only those slides maintained continuously at 90% R.H. developed mycelium from the honey-dew droplets. Mycelium grew later on those slides maintained at 90% R.H. for 8 or 16 hours in each 24 hours, but not in those kept at 90% R.H. for 4 hours (Table VIII).



TABLE VIII

CUMULATIVE EFFECT OF VARIOUS PERIODS OF EXPOSURE AT  
90% R.H. ON SPORE GERMINATION OF *C. sphaerospermum*

| Period (in hours) of exposure<br>in each 24 hours | Cumulative period (in hours) before<br>significant hyphal development |
|---------------------------------------------------|-----------------------------------------------------------------------|
| 4                                                 | $\infty$                                                              |
| 8                                                 | 130                                                                   |
| 16                                                | 88                                                                    |
| 24                                                | 70                                                                    |

The implication of these observations appears to be that a very low population of white-flies can produce sufficient honey-dew to initiate sooty mould development as long as the humidity reaches 90% on at least 14 consecutive nights. Dryer conditions during any period of hyphal development would prolong the time required to initiate sooty mould, and if such conditions persisted would no doubt prevent entirely the growth of this fungus.

### Conclusions

It is evident from the copious production of honey-dew by the later instars of *Trialeurodes* that even light infestations will result, under moist conditions, in the development of some sooty mould. Reduction in crop yield, however, is not to be expected until the attack has reached moderate proportions, of some 70 scales per  $\frac{3}{4}$  inch disc, at which population level about 70% of the fruit picked was entirely free from mould in the experiment reported. Heavier infestations (130 scales per  $\frac{3}{4}$  inch disc) further reduced the yield, and the amount of clean fruit fell sharply to about 13%.

While the presence of this mould does not appreciably impair the quality of the fruit, except perhaps in very heavy infestations, it makes it necessary to clean all such fruit before marketing—a laborious and time-consuming procedure.

There is some evidence to suggest that heavy infestations on young plants may subsequently have an adverse effect on the setting of fruit if allowed to go unchecked. The height growth of infested plants is not impaired unless initial infestation occurs when the seedlings are very small.

In future experiments on the biological control of white-fly it is apparent that the steady density about which the populations should fluctuate should not exceed a mean of 20 scales per  $\frac{3}{4}$  inch disc on the upper leaflets throughout the life of the plant.

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## 8. FAILURE OF SYSTEMICALLY-DISTRIBUTED CHEMICALS TO PREVENT SPREAD OF TMV IN TOMATO

*by*

**R. HOWLES**

Several chemicals are known to inactivate viruses when mixed with them *in vitro*; some that become distributed systemically in tomato plants were tested to find out if they would stop or decrease the spread of tobacco mosaic virus from infected to healthy plants.

TABLE

EFFECT OF SEVERAL CHEMICALS ON THE SPREAD OF TMV BETWEEN TOMATO PLANTS

| Experi-<br>ment | Starting date<br>and duration   | Chemical                                                     | Concentration<br>(p.p.m.) and<br>application | No. of plants<br>infected/No.<br>exposed to<br>infection |
|-----------------|---------------------------------|--------------------------------------------------------------|----------------------------------------------|----------------------------------------------------------|
| 1               | 18th May, 1956<br><br>83 days   | $\alpha$ -Phenoxyiso-<br>butyric acid                        | 50, leaf                                     | 2/8                                                      |
|                 |                                 | $\alpha$ -(4-chlorophenoxy)<br>isobutyric acid               | 50, leaf                                     | 3/8                                                      |
|                 |                                 | 2, 4, 6-Tri-<br>chlorophenoxy-<br>acetic acid                | 50, leaf                                     | 1/8                                                      |
|                 |                                 | $\beta$ -(2, 4, 6, -Tri-<br>chlorophenoxy)<br>propionic acid | 50, leaf                                     | 3/8                                                      |
|                 |                                 | Wetter                                                       |                                              | 9/32                                                     |
|                 |                                 | Unsprayed control                                            |                                              | 10/32                                                    |
| 2               | 18th Oct., 1956<br><br>96 days  | Phenoxyacetic acid                                           | 50, leaf                                     | 4/8                                                      |
|                 |                                 | 2, 3, 4, 5, 6-<br>Pentachloro-<br>phenoxyacetic acid         | 50, leaf                                     | 5/8                                                      |
|                 |                                 | Wetter                                                       |                                              | 7/16                                                     |
|                 |                                 | Unsprayed control                                            |                                              | 9/16                                                     |
| 3               | 7th May, 1957<br><br>64 days    | 2-Chlorophenoxy-<br>acetic acid                              | 400, soil                                    | 3/16                                                     |
|                 |                                 | 2, 4-Dichloro-<br>phenoxyacetic acid,<br>ammonium salt       | 5, soil                                      | 9/16                                                     |
|                 |                                 | Malachite green<br>Control                                   | 250, soil                                    | 10/16<br>18/48                                           |
| 4               | 17th Sept., 1957<br><br>72 days | 2-Chloro-<br>phenoxyacetic acid                              | 400, soil                                    | 8/32                                                     |
|                 |                                 | 2, 4, 6-Tri-<br>chlorophenoxy-<br>acetic Acid                | 50, leaf                                     | 10/32                                                    |
|                 |                                 | Control                                                      |                                              | 11/32                                                    |
| 5               | 15th Apr., 1958<br><br>55 days  | Eosin                                                        | 50, soil                                     | 5/16                                                     |
|                 |                                 | Control                                                      |                                              | 8/16                                                     |
|                 |                                 | Thiouracil                                                   | 25, soil                                     | 6/16                                                     |
|                 |                                 | Control                                                      |                                              | 13/16                                                    |
| 6               | 12th Aug., 1958<br><br>55 days  | Eosin                                                        | 100, 50, soil                                | 13/40                                                    |
|                 |                                 | Thiouracil                                                   | 50, 25, soil                                 | 17/40                                                    |
|                 |                                 | Control                                                      |                                              | 15/40                                                    |

Replicates of five tomato plants, variety 'Potentate', were grown in pots in lines across a bench. The second leaf of the outer plant in each line was inoculated with a mild strain of tobacco mosaic virus when the plants reached the five leaf stage. When these plants showed symptoms, the following treatments were applied: (1) sprayed with the requisite solutions, using 1 in 500 Shellestol as a wetter, (2) 200 ml. per pot of solution watered on the soil, (3) sprayed with the wetter alone. Other plants were left untreated as controls. The plants in each line were then placed close together so that virus could spread when the plants rubbed together during growth. The treatments were repeated 14 and 28 days later. Treatment (2) sometimes injured the plants, and so later applications were omitted.

The plants were tested for TMV six weeks after treatment, and then at ten day intervals during the next six weeks, by inoculating sap from young leaves to *Nicotiana glutinosa*. No treatment prevented, or significantly delayed, the spread of virus (see Table).

Leaf distortion was severe with 0.005% and 0.001% 2, 4, 6-trichlorophenoxyacetic acid in spring, with 0.005% phenoxyacetic acid in autumn, and with 0.0005% 2, 4-dichlorophenoxyacetic acid, ammonium salt in spring; moderate distortion occurred with 0.005% 2, 3, 4, 5, 6-pentachlorophenoxyacetic acid in autumn, and slight distortion with 0.0001% 2, 4, 6-trichlorophenoxyacetic acid in spring, 0.005% 2, 4, 6-trichlorophenoxyacetic acid in autumn, 0.001% phenoxyacetic acid in autumn and 0.04% 2-chlorophenoxyacetic acid in spring.



## 9. SOME EFFECTS OF SALTS ON MUSHROOM PESTS AND DISEASES

by

P. B. FLEGG and I. J. WYATT

Mushroom growers have claimed for many years that the application of a salt, usually sodium chloride, to the casing layer has brought about an improvement of crop quality and a certain freedom from pests and diseases. Although experiments have been carried out by Stoller (4) and Edwards (1) no conclusive results were obtained to show whether these claims have any foundation.

Flegg (2 and 3) has now produced experimental evidence to support the first claim, that of improved quality. As a result of incidental observations made during further experiments, in which various salts were added to both the compost and casing layer, there is now some evidence to show that the claims concerning pests and diseases may also have some foundation.

### Diseases

During the course of two experiments (nos. P.17 and P.18) observations were made on the occurrence of *Mycogone perniciosa* Magnus. Plant pots, 8in. in diameter, were filled with compost, peak heated and spawned in the usual way, but were unintentionally cased with soil infected with *Mycogone*. The soil was applied moist but on the basis of 1Kg. of dry soil per pot. Calcium chloride solutions were added to the casing and/or compost and an equal amount of water was applied to pots receiving no salt.

The disease was duly noted on a number of the pots, and, by removing the infected material and treating the surrounding area with formalin, the outbreak was prevented from spreading. It was, however, soon noticed that the occurrence of the disease was restricted largely to the pots to which no salt had been added.

Tables I and II show the numbers of infected pots observed in the two experiments. From Table I it can be seen that, of the pots which had no calcium chloride added to the casing layer, all became infected. The disease was found on only two pots out of the eighteen which received an addition of salt to the casing layer. This difference between treated and untreated pots is statistically significant.

TABLE I  
EXPERIMENT P.17  
EFFECT OF CALCIUM CHLORIDE LEVEL  
ON THE OCCURRENCE OF *Mycogone*

| Salt added to casing layer<br>(g. per pot) | Number of infected pots<br>(out of 6) |
|--------------------------------------------|---------------------------------------|
| 0                                          | 6                                     |
| 5                                          | 0                                     |
| 10                                         | 2                                     |
| 15                                         | 0                                     |

TABLE II

EXPERIMENT P.18

EFFECT OF CALCIUM CHLORIDE LEVEL ON THE OCCURRENCE OF *Mycogone*

| Salt added<br>to compost<br>( <i>g. per pot</i> ) | Salt added to casing layer ( <i>g. per pot</i> ) |    | Totals<br>(out of 24) |
|---------------------------------------------------|--------------------------------------------------|----|-----------------------|
|                                                   | 0                                                | 10 |                       |
|                                                   | Number of infected pots (out of 12)              |    |                       |
| 0                                                 | 10                                               | 2  | 12                    |
| 10                                                | 6                                                | 3  | 9                     |
| Totals (out of 24)                                | 16                                               | 5  | 21                    |

As far as adding salt to the casing layer is concerned, Table II shows the same trend. Of the pots which received no salt in the casing layer, 16 out of 24 became infected, compared with only 5 out of 24 to which salt was added. This difference was found to be highly significant.

Additions of salt to the compost made little difference; 12 of the pots without salt in the compost and 9 of the treated pots became infected. This is not surprising for *Mycogone* is known to be soil-borne, and conditions in the compost would not be expected to affect it.

It is open to speculation whether this effect on *Mycogone perniciosus* is due to increase of osmotic pressure or to direct toxicity of calcium chloride, although this salt is not specifically toxic to mushrooms.

### Pests

Another experiment (no. P.12), from which the pest data were obtained, was also carried out in 8in. plant pots which were treated as already briefly described. The salt used in this experiment was calcium nitrate. Nil, 10 and 20g. of this salt were added to the compost, together with the same three levels to the casing layer, making nine combinations in all. The experiment was designed as a  $9 \times 9$  Latin square.

At the end of cropping, core-samples were removed from the pots in four of the rows, and 20g. of compost from each sample extracted with water in Baermann funnels. The larvae so obtained were mainly Sciaridae, the species almost certainly being *Lycoriella fenestralis* (Zett). A few Sphaeroceridae (*Leptocera heteroneura* Hal.) and Cecidomyiidae (*Mycophila speyeri* Barnes) were also found. The results for Sciaridae are of particular interest. Table III shows the treatment totals of larvae and also the combined totals for the various salt levels in both casing layer and compost.

It is at once obvious that increasing salt, in both the casing layer and the compost, progressively decreases the number of Sciarid larvae present. The effect is most marked with salt in the casing layer. Statistical analysis of these results confirms these observations, and shows a significant linear reduction of Sciarids by salt in both compost and casing layer.

Since the extracted samples were of compost only, it is interesting that the salt in the casing layer had a greater effect on the compost population than salt in the compost itself. The most likely explanation is that the presence of salt discouraged the flies from oviposition, rather than causing the death of the larvae.

TABLE III  
EXPERIMENT P.12  
EFFECT OF CALCIUM NITRATE ON SCIARID POPULATIONS

| Salt added to compost<br>( <i>g. per pot</i> ) | Salt added to casing layer ( <i>g. per pot</i> ) |    |    | Totals |
|------------------------------------------------|--------------------------------------------------|----|----|--------|
|                                                | 0                                                | 10 | 20 |        |
|                                                | Numbers of Sciarid larvae                        |    |    |        |
| 0                                              | 48                                               | 22 | 8  | 78     |
| 10                                             | 24                                               | 24 | 3* | 51     |
| 20                                             | 24                                               | 4  | 3  | 31     |
| Totals                                         | 96                                               | 50 | 14 | 160    |

\*Includes an estimate for a missing plot

The pest status of Sphaeroceridae is open to doubt, but it is nevertheless of interest that despite lower numbers they showed a similar reaction to salt as did the Sciariidae. Table IV appears to show, however, that salt in the compost has the greater effect with these larvae.

TABLE IV  
EXPERIMENT P.12  
EFFECT OF CALCIUM NITRATE ON SPHAEROCERID POPULATIONS

| Salt added to compost<br>( <i>g. per pot</i> ) | Salt added to casing layer ( <i>g. per pot</i> ) |    |    | Totals |
|------------------------------------------------|--------------------------------------------------|----|----|--------|
|                                                | 0                                                | 10 | 20 |        |
|                                                | Numbers of Sphaerocerid larvae                   |    |    |        |
| 0                                              | 11                                               | 1  | 6  | 18     |
| 10                                             | 1                                                | 0  | 1  | 2      |
| 20                                             | 0                                                | 0  | 0  | 0      |
| Totals                                         | 12                                               | 1  | 7  | 20     |

It is also worthy of note that the five Cecid larvae found in the samples were all from one plot which had no salt added either to the casing layer or compost.

From these and other observations (2 and 3) it seems that the practice of applying a salt to the casing layer, in order to improve crop quality and as a crop protection measure, is basically sound. It is not possible at this stage to suggest optimum rates of application. An attempt to assess this practice in economic terms must balance possible advantages of increased size of mushrooms and any protection from pests and diseases against the almost inevitable reduction of yield (2).

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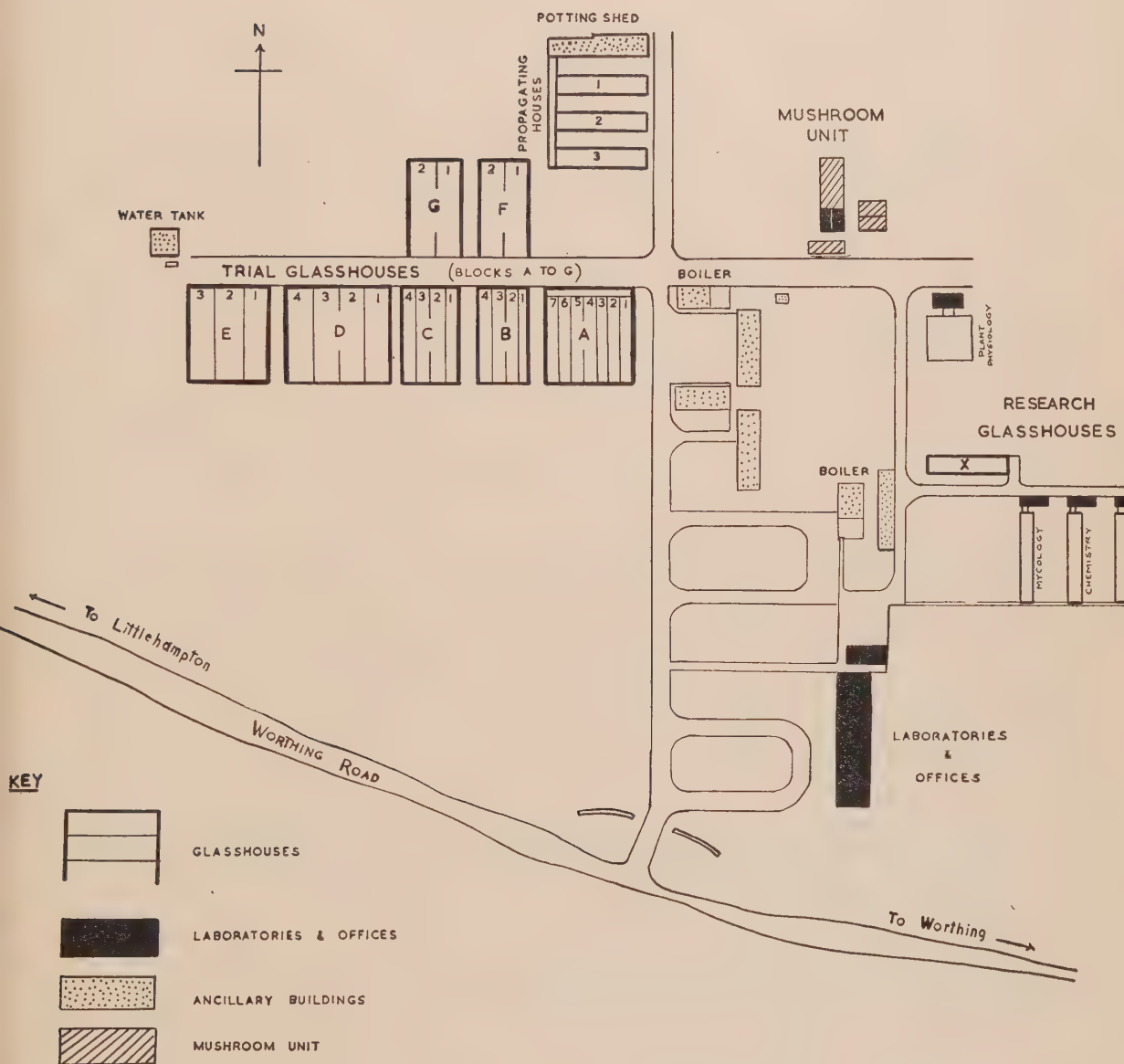


## APPENDIX

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Layout of the glasshouses, laboratories and other buildings

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## THE JOURNAL OF HORTICULTURAL SCIENCE

THE JOURNAL OF HORTICULTURAL SCIENCE, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editor at East Malling Research Station, Maidstone, Kent.

Papers in the current VOLUME 34 (1959) come from both the sponsor Stations, also Bayfordbury, Rustington, Wellesbourne and Mylnefield, from Reading and Nottingham Universities and from the N.A.A.S; from Johnstown Castle College, Eire, the Citrus Station, Nelspruit, S. Africa and the Cocoa Research Institute, Ghana.

Of particular interest to growers of glasshouse crops are two papers on the growth of fruits and leaves and a study of the effect of early environment on the development of flowering in the tomato, while another paper on the effects of soil salinity on that crop is in preparation.

Pertaining to fruit research, subjects include apple root-stocks and their resistance to disease; root development of apples, the effect of magnesium deficiency on their cropping and studies of wood infections due to *Gloeosporium perennans*; the effects of environment on raspberries and of biennial bearing on the chemical composition of apple leaves; the performance of selected navel oranges; temperature as affecting the frost resistance of apple flowers, and also chrysanthemums; strawberry eelworms and apple viruses; the effects of shade and manuring on cocoa and a study of the design of experiments on that crop. There are also papers on vegetable research covering weed effects on onions and beet, and irrigation of cauliflowers; an instrument for measuring the firmness of brussels sprouts is described.

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